DESIGN OF E-HEALTH APPLICATION TO ENHANCE HEALTH INFORMATION QUALITY: THE CASE OF A DIGITAL ALLERGY CARD

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DESIGN OF E-HEALTH APPLICATION TO ENHANCE
HEALTH INFORMATION QUALITY: THE CASE OF A
DIGITAL ALLERGY CARD

Research Paper
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Abstract
Information quality is a crucial requirement in healthcare because physicians and patients need structured, accessible, reliable, accurate and secure information for optimal patient treatment. Despite this crucial character, studies on information quality remain limited because they focus on evaluating and suggesting partial solutions after implementing e-health applications containing the information. They often neglect the design phase, where many problems could be avoided. This study seeks to address allergy information quality problems during a digital allergy card design through action design research. The evaluation phase was conducted through interviews with patients and physicians. We used thematic analysis to identify the different codes linked to the dimensions of information quality. We deduced five design principles. In addition to the implications of design principles for both practice and research, this paper highlights the importance of considering the dimensions of information quality individually or combining each other to build the e-health application features.

Keywords: Digital allergy card, e-health application, action design research, information quality.
1 Introduction

The importance of e-health applications has been discussed widely in information system literature because they can facilitate patient management and guarantee quality care (Sherer, 2014). Indeed, the most cited benefit of health application is related to the various dimensions of information quality (Chaudhry et al., 2006), which has been evaluated as determining therapeutic decision-making factors (Buntin et al., 2011). Another aspect that highlights the importance of information quality is the case of self-management by patients. In this case, patients use the e-health application's information to act on their health without a doctor's direct assistance (Roehrs et al., 2017). Thus, low quality of one dimension of the information quality can hamper the care journey (Dobrow et al., 2019).

Information quality refers to the extent to which the information conforms to an organisations' or individuals' needs (Zhu et al., 2014). This concept encompasses several dimensions that characterise the information whose content and format fit with a particular context of use (Neely and Cook, 2011). The main dimensions that describe the information quality are completeness, consistency, timeliness, availability, accessibility, ease of understanding, security, privacy, and accuracy (Cruz-Correia et al., 2013, Laumer et al., 2017). Another conceptualisation relates information quality to the IT application that contains this information (Neely and Cook, 2011, Gorla et al., 2010, Lee et al., 2002, Häyrinen et al., 2008). In this way, we link the health information quality and the e-health applications that contain it. In this sense, medical informatics research report many health information quality issues related to health information accessibility, accuracy, traceability, security, and privacy (Leza et al., 2013, Vance et al., 2015).

Henceforth the number of projects to design, develop and implement e-health applications has increased to facilitate patient management by collecting, processing, and securing health information. First, the digitisation of health information has led to Electronic Health Records (EHRs) and clinical software used in hospitals (Häyrinen et al., 2008). This issue has evolved toward the accessibility of health information beyond institution boundaries, expanding the interest in centralised EHRs that compelled the information of different isolated EHRs or interoperability between these different isolated EHRs (Dobrow et al., 2019). More recently, the importance of controlling their information and data by the patients led to the implementation of Personal Health Records (PHRs). Health information is no longer held solely by healthcare organisations, but patients are empowered to manage their information (Wiljer et al., 2008, Archer et al., 2011).

Design methods of digital technologies in healthcare have also evolved toward end-users involvement to consider end-users needs (Haki et al., 2018). Among other aspects, user involvement allows integrating all the features to facilitate IT applications’ interactions after implementation (Shah and Robinson, 2006). Therefore, it is essential to have a global view of the various user profiles and needs when designing the e-health application (Payton et al., 2011).

However, despite the recurrence of information quality as an essential requirement for e-health applications (Huckvale et al., 2010, Gogan et al., 2013), most studies related to the quality of health information do not focus on the design phase but rather addressing information quality problems after implementing the IT application. Indeed, the extensive literature on information quality focuses on analysing the various dimensions and evaluation methods (Zhu et al., 2014). All these studies suggest that both preventive and corrective actions should be implemented (Grgec et al., 2015). Nevertheless, preventive actions taken into account during the design phase are particularly interesting because integrating a requirement after implementation is much more expensive (Meth et al., 2015).

We then propose the following research question: how do we prevent information quality problems during the design phase of an e-health application?

To answer this question, we use the Action Design Research (ADR) framework to consider the information quality requirements. More concretely, we start with the formulation of the problem. We relate the empirical manifestation of drug allergy information to the different dimensions of information quality. Then, in the Building, Intervention Evaluation (BIE) phase, we propose solutions for each of these dimensions based on existing work, best practices, and the user feedback we collect through
interviews. From this second phase, we deduce design principles that we improve iteratively throughout the process. We further generalised these design principles for the broader category of health information quality according to the stage of generalisation of the learning presented by Sein et Al. (2011).

The remainder of the paper is structured as follows. The following sections present the method, results, discussion, contribution, limits, and perspectives. The concluding remarks highlight the main contributions of design principles and their operationalisation in the concrete case of drug allergy to solve the health information quality issues associated with designing e-health applications.

2 Method

2.1 Action design research framework

ADR draws its theoretical foundations from research in design sciences that seeks to develop prescriptive design knowledge through building and evaluating innovative IT artefacts intended to solve an identified class of problems in a predefined organisational context (Hevner et al., 2004). This section will first focus on reviewing the literature on Design Science Research (DSR) and the position of ADR before describing the different stages of an ADR process.

DSR has its origins in artificial sciences (Simon, 1980). Several authors working on design sciences support that the interest of research in information systems is their applicability in innovative IT design (Benbasat and Zmud, 1999). Therefore, beyond explanatory, analytical, and predictive theories, researchers in information systems have been interested in design and action theories to define a precise scientific method to solve an identified class of problems (Spagnoletti et al., 2015). A class of problems represents a broad category of problems that can manifest empirically in various environments. Thus, a researcher in design sciences must deduce from resolving an example of a broader problem some knowledge that enriches the literature used to inform or solve the identified class of problem (Hevner et al., 2004).

Moreover, the outcome of a DSR can be an artefact and prescriptive knowledge that arises from the design process and use of that artefact. This prescriptive knowledge is also called design principles. It should be distinguished from those underlying the research process in design science. We will call this latter category of principles the guidelines based on the terminology used by Hevner et al. (2004). However, because the fundamental paradigm of research in design science is resolving a class of problems, it is essential to evaluate the fit between the proposed artefact and problem without forgetting the organisational context in which the problem was identified and the solution deployed. In DSR, as defined by Peffers et al. (2007), the evaluation process occurs after implementing the artefact in the organisational context (Gregor and Hevner, 2013). The result is that the design process and evaluation process are separated (Hevner et al., 2004). This approach evolved to ADR, which starts from the principle that the organisational context shapes the artefact during the design process and its use after implementation (Sein et al., 2011).

Suppose both DSR and ADR aim to solve practical problems. In that case, the starting point of an ADR process is a practical problem in an organisation rather than a theoretical design problem in DSR.

The ADR approach combines an action research methodology and the design research perspective to iteratively build and evaluate IT artefacts until a version ready for implementation in a specific organisational context is obtained. ADR involves two types of actors (Sein et al., 2011, Baskerville and Wood-Harper, 1996): (1) the ADR team made up of researchers and practitioners whom each bring both theoretical expertise for researchers and practical expertise for practitioners in the construction of the artefact and (2) end-users in the organisational context who are involved in evaluating the artefact considering the improvement during the design process. Both types of actors are essential when deciding whether the artefact is ready for implementation, as explained in the next section related to the ADR process.
The so-called end-users are critical in the design process to validate the artefact according to their needs. Thus, the ADR facilitates this end-users involvement from the early stages of the design process to formulate the problem and help achieve the most suitable solution iteratively. This method is particularly suitable for complex contexts such as the healthcare field that involve several stakeholders such as patients, physicians, regulators, and providers (Payton et al., 2011). The complexity of this context lies in the fact that the needs are challenging to capture, given the case impossibility of capturing a standard process corresponding to the general healthcare context. Mintzberg (1979) refers to this type of context as professional bureaucracy, characterised by professionals' autonomy in their work. Moreover, in professional bureaucracy, a routine cannot be established and standardised (Lunenburg, 2012, Abernethy and Stoelwinder, 1990).

Therefore, we argue for the relevance of the ADR approach in the context of this research. We will perform a case study related to developing a Digital Allergy Card (DAC) to solve an identified problem for drug allergy information as an instance of health information quality. This approach will enable us to iteratively improve the solution regarding feedback obtained from end-users because of the evaluation loops that we will perform throughout the process.

ADR process is a four stages methodology: (1) Problem formulation, (2) Building Intervention Evaluation (BIE), (3) Reflection and learning, (4) Formalisation of the learning (Sein et al., 2011).

### 2.2 ADR METHODOLOGY APPLIED TO THE DESIGN OF A DRUG ALLERGY CARD

This research project was initiated in March 2019 by an allergist and a researcher in information systems. After that, the hospital allergy unit manager, a researcher in allergology, was also involved. Both allergists work actively to manage allergic patients at the University Hospital of Montpellier (Montpellier, France). From their experience, they identified several problematic situations relating to drug allergy information. A PhD student in allergology and a technology company collaborated to develop a private blockchain to model a solution to allergy information traceability.

This research work was led by an industrial PhD student in information systems (hosted by the technology company) according to the different stages of an ADR, such as the formulation of the problem, BIE, reflection and formalisation of learning. The data were collected and analysed by physicians and patients during the first two phases using qualitative methods. The final two steps helped formulate the learning that emerged from the ADR process.

The ADR team described above clarified the problem and solution during three face-to-face team meetings and multiple email exchanges. At the end of these exchanges, the current functioning of healthcare processes regarding drug allergies had been described by allergists.

![Figure 1. Process of drug allergy information](image-url)
We analyse this process to identify problematic situations in terms of process weaknesses or shortcomings. Thus, we have grouped problematic situations about the different dimensions of information quality and then focused on the existing solution's weaknesses.

This problem formulation allows us to start the phase of BIE performed in three cycles. The modelling of the solution was performed by both PhD students and the development of the application by an IT developer of the technology company. The intervention and evaluation were performed concurrently at the University Hospital of Montpellier. Two interview rounds (mock-up and alpha version) were performed. The first round of mock-up evaluation was considered in the second cycle of the BIE cycle. The second round of alpha-version evaluation is considered during the third cycle.

The data were collected using semi-structured interviews. Sixteen interviews were conducted, lasting 25 minutes on average. The interviews were audiorecorded and transcribed. Relevant themes were inferred by both the first and second authors separately and on different transcribed interviews using inductive thematic analysis, inspired by grounded theory (Corbin and Strauss, 1990, Sekimoto et al., 2006) and adapted by Gioia et al. (2013). All the interviews were first coded by a first code, closed to respondents' words. Next, a more general coding was performed according to the dimensions of information quality. The resulting coding scheme was discussed within the research team (comprising allergists and both researchers in information systems, including the PhD student). Disagreements were discussed until a consensus was achieved (Zwaanswijk et al., 2011). The design principles have been deduced from the coding process. They have been translated into features and implemented to develop the artefact in the form of a digital application. The formulation of the design principles follows the model proposed by Gregor et al. (2020).

**Figure 2. Research process**

### 3 APPLICATION OF ACTION DESIGN RESEARCH

This section presents our research process results according to Gregor and Hevner (2013). They assume that the results section can describe the design process.

#### 3.1 Problem formulation

The formulation of the problem led us to identify the problem of the quality of allergy information. Indeed, from the manifestation of the process described by allergists, we have identified the different manifestations of the problem according to the different dimensions of the quality of information presented in Table 1. The first column of Table 1 reports the different aspects of the allergy information quality problem that we identified—the second column reports how each dimension occurs during the lifecycle of allergy information. The third column reports the corresponding dimension of information quality.
The problems summarised in Table 1 above relate to drug allergy information quality that can hamper the decision-making process in terms of drug prescriptions and lead to many consequences. First, the re-administration of risky drugs can lead to fatal anaphylactic reactions. However, alternative medications may be less effective and cause antibiotic resistance (Golden et al., 2011). Thus, we argue that the case of drug allergy as described above is an example of a class of problems related to information quality in the sense of Sein (2011).

Among the existing solutions described in the process, we find that each one can solve the problem only partially. The paper format allows the patient to carry the information with him/her every time he/she has a medical appointment; this implies that a new document must be issued for each additional piece of information. The EHR report allows the information to be accessible only within the health care facility. To address this weakness, solutions for interoperability or centralisation of health data have been developed. These solutions raise other issues such as data security and privacy. More generally, several solutions are proposed to address specific aspects of the information quality problem in e-health applications. Although these solutions, taken in isolation, respond to the problems they address, we can identify that other dimensions may be neglected by addressing one dimension of the information quality problem. Even adverse effects may be exerted on another dimension (Nguewo Ngassam et al., 2020).

In other words, one of the weaknesses of existing solutions consists in the fact that the dimensions of information quality are treated in isolation when they can have impacts on each other (Lee and Haider, 2013).

### 3.2 Building, intervention, and evaluation (BIE)

During this second stage, we consider the different dimensions of information quality.

Starting with the description of the current process’s weaknesses, we propose to build a DAC that will allow organising the information that until now was either non-existent, inaccessible, unreliable and scattered on several tools (paper and EHR).

The first cycle started with the Design Principles (DP) of information collection, user-controlled transparency and information validation.

**DP1. Information collection:** The e-health application should have features for patients and physicians to enter complete information for a clinical purpose.

This DP addresses the dimension of information availability and completeness. According to this DP, the health application should provide features that users will use to enter and save the system’s information. This principle is operationalised on the artefact by the features to enter a new allergy reaction that allows the user to fill out a form. The form includes information about the medication, the date of the reaction, the severity, photos in case of skin reactions, and a comment field to allow the user to fill in more details about the reaction.

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<table>
<thead>
<tr>
<th>Manifestations in the process of drug allergy information</th>
<th>Description</th>
<th>Information quality dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The patient or the physician does not report the allergy information.</td>
<td>Ignorance of a patient’s allergy</td>
<td>Availability</td>
</tr>
<tr>
<td>Storage of allergy information in EHRs. Paper documents must be carried all the time. Paper documents can be easily lost.</td>
<td>Storage of allergy information in isolated systems Lack of interoperability between systems Information loss or inaccessibility</td>
<td>Accessibility</td>
</tr>
<tr>
<td>The allergy information does not differentiate between allergy tested and susceptibility of allergy.</td>
<td>Self-reported information Confusion between self-reported and confirmed information</td>
<td>Accuracy</td>
</tr>
<tr>
<td>Several ways to report drug allergy information</td>
<td>The information is not structured.</td>
<td>Structuring</td>
</tr>
</tbody>
</table>

*Table 1. Identified problems and their manifestation*
DP2. User-controlled transparency: patients, trusted third parties, and physicians should access patient information under patients' control.

This DP addresses the information accessibility dimension that defines how different users can access the application's information. However, due to legal constraints and good practices, access to health information must be controlled by the patient himself. This principle is operationalised by the access granting feature that the patient can use to give registered physicians access to an account in the application and other patients as a trusted third party.

DP3. Information evaluation: with the artefact, physicians should confirm or infirm the information reported by the patients.

This DP addresses the information accuracy dimensions that define the extent to which the allergy information agrees with the patient's current status.

During this first cycle of BIE, the building part was performed by researchers in information systems, particularly the first author of this paper for the drafting of specifications, UML modelling of the solution and design of interactive models (wireframes). These different deliverables were discussed and improved during the intervention and evaluation, which comprised team meetings and formative evaluations (Venable et al., 2016) with six patients.

The first BIE cycle produced a supplementary principle—Structuring and hierarchisation of the information.

During the second BIE cycle, we consider the four design principles mentioned above. The construction was carried out by an IT developer of the DAC and the industrial PhD student, who ensured that all the team meetings' specifications were considered in developing the e-health application and the first BIE cycles' outputs. We performed another round of evaluation with ten (10) potential end-users (five patients and five physicians). Therefore, we deduced a supplementary design principle—information understandability and revised the four design principles that we previously get.

At the end of the first two cycles, the principles deduced are considered input for the third cycle under development and will make it possible to highlight the beta version of the application.

<table>
<thead>
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<th>First code</th>
<th>General Code</th>
<th>DP</th>
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<td>Patient 4: &quot;In this kind of thing, I am complete, I find that it is good, it is good because we do not always have the memory, it is not a question of age, we have not always the memory of the dates of the facts, things like that, it goes into oblivion and then …&quot;</td>
<td>Forgetting allergy information without a registration system and traceability system</td>
<td>Availability and completeness</td>
<td>Real-time information collection and editing</td>
</tr>
<tr>
<td>Patient 2: &quot;After the doctor could correct, it can be interesting.&quot;</td>
<td>Interest in the information corrected by the physician</td>
<td>Editing for accuracy</td>
<td></td>
</tr>
<tr>
<td>Physician 1: &quot;Usually they tell you they are allergic to the Augmentin because they had belly pain or ... Well, often it is not proven. And after, I try to ask questions, to make up my mind if it was a severe reaction or not.&quot;</td>
<td>The information declared by the patients is not sufficient, and the physician tries to support the diagnosis by his interrogation</td>
<td>Accuracy</td>
<td>Continuous evaluation of the information</td>
</tr>
<tr>
<td>Patient 5: &quot;My doctor saved it on my computer, but I think the information is not there. It was not accessible for the dentist, for other physicians.&quot;</td>
<td>Allergy information is recorded in the isolated system of the physician or health facility</td>
<td>Accessibility</td>
<td>User-controlled transparency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Privacy</td>
<td></td>
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Verbatims: First code: General Code: DP

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<td></td>
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<td></td>
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</tbody>
</table>
Table 2. Coding of the interviews and deduction of design principles

<table>
<thead>
<tr>
<th>Principles</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real-time information collection and editing</td>
<td>Render the information available for further use as soon as that user is aware of the information (anticipated)</td>
</tr>
<tr>
<td></td>
<td>A delayed information entry can hamper the completeness and even the availability of the information (unanticipated)</td>
</tr>
<tr>
<td></td>
<td>Next of kin must be able to enter information and be granted access to the physician on behalf of the patient (unanticipated)</td>
</tr>
<tr>
<td>Continuous evaluation of the information</td>
<td>Guarantee the accuracy of the information (anticipated)</td>
</tr>
<tr>
<td></td>
<td>Re-evaluate the information after a certain period (unanticipated)</td>
</tr>
<tr>
<td>User-controlled transparency and institutional accessibility</td>
<td>Facilitate the access of the information by different physicians and next of kin (anticipated)</td>
</tr>
</tbody>
</table>

3.3 Reflection and learning

Based on what emerged from the BIE phase, more particularly from the evaluation in use, we revised and completed the principles initially considered.

**DP1. Real-time information collection and editing:** The e-health application should have features for patients, next of kin, and physicians to enter and edit health information as soon as possible to complete and consistent for the clinical purpose.

**DP2. User-controlled transparency and institutional accessibility:** Patients, trusted third parties, and physicians and healthcare institutions should access patient information so that patients in the health application control.

**DP3. Continuous evaluation of the information:** the health application should have features to edit the allergy information status (self-reported, confirmed, ruled out) and alert for a re-evaluation of the information.

Additionally, two other principles have been added as follows:

**DP4. Structuring and hierarchisation of the information:** the e-health application should have features that allow the organisation of information according to the status and chronology.

**DP5. Information understandability:** the e-health application should contain comprehensible information for patients and physicians to enter or use quality health information.

At the end of this process, specific outputs had not been planned from the literature review. However, they emerged during the application’s confrontation in the context of use, such as the importance of taking photos when a cutaneous reaction occurs (see Table 3). However, these results can be applied to other health information with the same purpose and subject to the same constraints according to the law and regulations.
Table 3. Consequences of the Building, Intervention and Evaluation step

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need to grant access to the hospital rather than an individual physician</td>
<td>(unanticipated)</td>
</tr>
<tr>
<td>Information understandability</td>
<td>Guarantee that the stakeholders understand each other (anticipated)</td>
</tr>
<tr>
<td></td>
<td>Anticipate the possibility of a physician correcting erroneous or incomplete information (unanticipated)</td>
</tr>
<tr>
<td>Structuring and hierarchisation of the information</td>
<td>Set information in a well-organised way (unanticipated)</td>
</tr>
</tbody>
</table>

3.4 Formalisation of the learning

In summary, at the core of the literature on drug allergies, there is the central theme of allergy information, which is essential health information in the patient care process because it has direct impacts on patient safety, as mentioned above. Therefore, as an empirical example of a larger class of problem, health information quality, which the literature has often mentioned, is associated with current accessibility, traceability and security (Cruz-Correia et al., 2013, Kohli and Tan, 2016).

This articulation of the class of problems, the class of solutions, and the design principles for this class directly satisfied ADR's generalisation principle. The design principles define the design research (DR) contribution and represent design knowledge emerging from ADR application (Baskerville et al., 2018).

Additionally, the application, which will allow better patient care, contributes to the Action design research process.

4 DISCUSSION

This study's objective was to address information quality issues during the design process of an e-health application. We have used the case of drug allergy information that we have gone through the ADR framework.

Indeed, information quality has not often been addressed in the design of e-health applications. A few studies have addressed the dimensions of information quality in isolation, such as accessibility with the question of interoperability, security and privacy protection, and traceability (Roehrs et al., 2017).

The limitation of these studies lies in the fact that information quality issues are not addressed thoroughly. Indeed, when designing e-health applications, several information quality problems can be avoided (Gorla et al., 2010). In this study, we consider the multidimensional nature of information quality in identifying and addressing e-health application requirements.

During the problem formulation phase, we analysed the allergy information process concerning the different dimensions of information quality. We identified weaknesses related to the dimensions of availability, accessibility, accuracy and structuring of allergy information. We then considered each problematic dimension on its own before taking into account the complementarity with other dimensions (Lee and Haider, 2013). This complementarity emerges from the iterative evaluation that we conduct through the interviews with patients and physicians.

In summary, we conducted two BIE cycles. We deduced five design principles (or technological rules) applied during the design process to solve the targeted problem of allergy information quality (Mandviwalla, 2015). These design principles address one or more information quality dimensions.

4.1 Real-time information collection and editing

The initial principle related to information collection represents the entry of information in the application by users. We initially considered only the patients and the physician for this purpose. However, the iterative evaluation process showed that the trusted third party could also be involved in this action on behalf of the patient when they cannot enter the information personally. All these three stakeholders are identified by several authors (Payton et al., 2011, Mantzana et al., 2007).
Later, we added a temporal consideration in the postponement of information to favour instantaneous capture to ensure that no part of the information is forgotten. This point was made because some patients mentioned the risk of forgetting the exact circumstances when the reaction started, especially when the procedure to get an appointment with the physician is long.

This principle impacts the dimensions of availability, completeness, timeliness and accuracy of the information. Availability and completeness are provided when the information is collected. At the same time, the circumstances surrounding the collection may impact timeliness and accuracy.

4.2 User-controlled transparency and institutional accessibility

The principle of transparency refers to the need to make information accessible and visible to the actors involved in patient care. In our specific case, we offer two access modes: (1) Through interoperability between the application and existing systems (Dobrow et al., 2019) and (2) Directly on the application for physicians who will have downloaded and created an account. The first mode has the advantage that it eases physicians who will not have to manage additional software. This element is all the more critical as it has been evaluated as a determinant of physicians' adoption of e-health applications (Detmer et al., 2008).

However, the health sector requirements and patient expectations include privacy constraints (Fernández-Alemán et al., 2013, Wiljer et al., 2008). Therefore, patients themselves should choose who should have access to their information by granting them access rights. Thus, we added user control. However, this control can be overridden in emergencies when an explicit agreement of the patient or a relative cannot be collected. The patients can grant access to the physician and a trusted third party.

In contrast, a trusted third party can grant access to the physician. However, when the DAC is connected to the hospital's software described in mode 1, the patient can access the entire facility globally, knowing that it may involve several physicians during a stay in the hospital. This latest consideration is an unanticipated outcome of this principle. Indeed, the access by individual physicians can be limited. Thus we argue for institutional accessibility.

This principle highlights the link between accessibility and privacy. Several studies in this direction show that the more accessible the information, the greater the privacy concerns (Li et al., 2010).

4.3 Structuring and hierarchisation of the information and continuous evaluation

Capturing information open to all stakeholder profiles can have advantages, as explained above, regarding the information's availability and completeness. However, structuring the information would be essential to distinguish between the information entered by the patients and that evaluated by the physicians. Thus, we propose the principle of information structuring and hierarchisation. This principle is supported by many physicians concerned about the accuracy of the information they use to prescribe the proper treatment. This is consistent with recommendations in the literature about the accuracy of information about adverse drug reactions.

Drug allergies are one category of Drug Hypersensitivity Reactions (DHR). DHR may be classified into several other categories based on two main factors: the reaction's immunological nature and its severity (Ferner and McGettigan, 2020). Depending on this classification, different therapeutic decisions may be made. The label of "drug allergy" itself corresponds to immune reactions and, in the case of low severity and lack of proofs (no allergy work-up), a physician may decide to override this label instead of taking a less effective alternative drug (Ferner and McGettigan, 2020). Thus, drug allergy documentation must be sufficiently detailed to structure information to guarantee the patient's safety.

Globally, the importance attached to the accuracy of health information requires evaluating this information by the physicians (Tang et al., 2006), creating confusion if a distinction between the information reported by the patients and assessments is not made. This principle also considers the chronological organisation of the data, making it possible to provide information on the various changes in the information over time and possibly alert the importance of a re-evaluation.
4.4 Information understandability

Patients' involvement in the care process through personal health records requires usability aspects that involve both interfaces and content (Khajouei and Farahani, 2020). Indeed, the content should be understandable so each actor can easily report and use the application's information. This principle is fundamental because it can prevent problems with patients' quality of information using the application. During the assessments, patients reported a lack of clarity in a field they were asked to complete or a different understanding than the correct one. Because of this lack of understanding, patients could fill out inaccurate and irrelevant information to the physician.

However, if patients understand the application's content, they will give the best information concerning their situation. Thus, we argue from the principle of information understandability that the more the content of the application will be understandable by users, the more precise the information entered.

An unanticipated outcome of this principle that emerges from the interviews is that patients may unconsciously enter incorrect information. For example, the name of the drug that caused the reaction may be entered incorrectly. Therefore, we have provided a feature that allows the physician to correct the information while confirming or denying the self-reported information.

4.5 The resulting Digital Allergy Card

As a result of our ADR process, we present a DAC. This e-health application includes a new process for drug allergy information. The e-health application menu comprises several tabs on the patient side, including allergy follow-up and management, physicians, access control, messaging, agenda, and trusted third party (see Figure 3).

The first essential element with the resulting DAC is the identification/authentication feature that uses services to verify each user's identity on the application. The second important element of the application is related to the allergy information process from the user reporting to the status change. Compared to what already exists, this health application allows to standardise and structure the allergy information. The process of allergy information would then be simplified.

The process always implies that both the patient and the physician can update allergy information with complete traceability and logging of the whole chronology of events.

A private blockchain is used to ensure the robust traceability of allergy information. In summary, the multitude of stakeholders concerned in this DAC project (Kohli and Tan, 2016), uses a decentralised system attractive, particularly considering the need for reliable and accurate allergy information for therapeutic decision making. Moreover, the solutions currently used to track allergy information are disparate; when centralised for better accessibility, they are dumped into the shared medical record in the form of a stack of PDFs, which are accurate but are not directly visible. To improve the structuring, the abovementioned level of accuracy is met in our case by robust traceability of the information through the blockchain (Nguewo Ngassam et al., 2020). Blockchain technology was discussed with patients and physicians during the evaluation phase. The feedback we have had about blockchain revolves around the reliability, accuracy and traceability of the allergy information that the artefact can provide. Indeed, users focused on what the digital allergy card could bring them to manage their health information.

The listing of allergies for any patient is labelled using a colour code to distinguish levels of validation and severity of the allergy attached to it. For each selected allergy of a patient, DAC displays the whole chronology, tests, and validations among all the involved health professionals.
5 Contributions

We made contributions both for research and practice in this study that are represented by the design principles. The design principles represent a sufficient contribution for research, according to Gregor and Hevner (2013). They discussed that the artefact and design principles are the primary outcomes of DSR and ADR. More specifically, the design principles make it possible to fill the gap in our understanding of how to address health information quality during an e-health application design. Our study shows that each dimension of health information quality should be considered individually and then the relationships between two or more dimensions to increase the health information quality during the design process of a mobile health application. For example, our study shows the link between availability, completeness, timeliness and accuracy. This study provides a global view of health information quality in e-health application design projects, thus complementing the partial view we have in other studies that often focus on a micro aspect of a health information quality dimension. For example, several studies deal only with the issue of accessibility through interoperability (Azarm et al., 2017), others deal with security and privacy (Fernández-Alemán et al., 2013), and still, others deal with traceability (Cruz-Correia et al., 2013).

As a practical implication, these design principles can be activated during the design processes of e-health applications. Indeed, each design principle should lead to the development of one or more application features.

6 Limitation and perspective

The main limitation of this study is that it only addresses one case, that of drug allergy information. However, the richness provided by other cases makes it possible to complete or validate the design principles that we have proposed, mainly because the features of an e-health application depend on the type of this health application (Jiang and Cameron, 2020). Therefore, further research is needed to complement and validate the proposed design principles. Thus, we suggest evaluating more cases using the ADR approach to solve the health information quality problem.

7 Concluding remarks

This study describes how to address information quality design during an e-health application design. We used different stages of the information lifecycle. We deduced five design principles that can
improve the different dimensions of information quality. We applied these design principles during a case study that we carried out related to drug allergy information quality. As a result, we obtained theoretical and practical contributions. Theoretically, our study addresses data quality explicitly, unlike other studies on the design of personal health records that focus on clinical needs. Practically, the design principles deduced make it possible to avoid health information quality issues by acting on different information quality dimensions during the design phase.
References


