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Toward Improving Adverse Drug Reactions Reporting from Twitter

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Abstract. *Adverse Drug Reaction (ADR) has become a central concern for many healthcare providers [15]. It is well-known that adverse reactions to drugs are a reason for several health problems. According to the Food and Drug Administration (FDA) estimation, ADRs are the 4th leading cause of death [15]. The prevalence of ADRs necessitates the establishment of a simple ADR reporting process. The ADR reporting process involves many stakeholders such as the FDA, the patient, and the health professional. The research uncovered a significant lack of communication among the stakeholders, thus the research goal is to improve this lack in communication. This research focuses on how to improve ADR reporting based on patients' posts on Twitter and also what solution can be provided to improve the communication between the patient and the doctor during the ADR reporting process. Therefore, this study proposes a solution to enhance such the communication between the stakeholders.*

Keywords: Health Informatics · Design Science Research (DSR) · Media Richness Theory (MRT) · Adverse Drug Reactions (ADRs) · Social Network · Twitter

1 Introduction

As Adverse Drug Reactions (ADRs) are considered one of the leading causes of death in health care [15]. Medical researchers have become increasingly interested in studying ADR due to its importance as a significant public health problem that can be prevented [15]. In fact, Sloane stated that ADRs are considered one of the main causes of illness, hospitalization, and mortality [10]. As a consequence, the drug reactions have received a considerable amount of attention by drug scientists and health professionals.

Recently, a study found that 42% of the patients involved in social networks discuss their current health conditions online [18]. Thus, social networks become a potential vital source of information to monitor the effects of medical drugs after they have been licensed [10], yet there are different issues when it comes to report an ADR from online data sources. One issue is that patients post their drug reactions on different social networks, such as Twitter, which does not necessarily mean their doctors will receive it. Another issue is that there are criteria that need to be fulfilled in order for the report to be recognized by the Food and Drug Administration (FDA) [9].

The propose solution addresses three objectives. The first objective is to provide a reliable solution that works as a communication channel between patients and health professionals. A second objective is to provide a solution that help the patient to report ADRs to their health professionals. A third objective is to provide a solution for health professionals to report ADRs through Twitter while taking into consideration the FDA criteria. The research questions focus on how the (ADR) reporting can be improved based on patients' posts on Twitter and also what solution can be provided to improve the communication between the patient and the primary doctor during the ADR reporting process. This study provides a reliable tool called an Easy Reporting (EZ-R) that will allow users to report ADRs and aims to enhance such communication, which will eventually benefit all involved stakeholders. To enhance a rich communication among stakeholders during the reporting process, this study draws upon Media Richness Theory (MRT) [13]. Section 3, explain the MRT as the theoretical foundation for the propose solution.

2 Background and Related Work

An Adverse Drug Reaction is defined as any serious undesirable experience that a patient has associated with the use of a medical product [2]. ADRs make around 30% of hospital admissions in the US and costs up to 30.1 billion dollars per year [16]. ADRs can occur to any number of patients after a drug enters the market. This led to the establishment of the ADR reporting processes.

The current ADR process has a few limitations. The ADR process involves many stakeholders, two of which must be present to complete a report. The FDA is one stakeholder and they are responsible for protecting the public health, investigating drug complaints, and monitoring drug reactions [12]. Either the patient or the doctor may submit an ADR to the FDA. Moreover, a new study found that 86 % of Adverse Events (AEs) went unreported [17]. Even if a patient files an online complaint, the process often poses a big challenge because the current online process has many limitations; according to Ying et. al. [8]. One of those limitations is the dependence on volunteers to report ADRs. This makes it a passive system that is limited by latency and inconsistency, which resulted a significant lack of communication between healthcare providers and patients. Therefore, a solution is needed in order to prevent more ADR related to deaths and costs for the country.

Today, patients are increasingly turning to social networks as a source for health-related information, health and wellness advice, and to share experiences [1]. According to a recent study, 26% of adult that use Internet discuss their personal health problems online and 42% of them discussing current conditions on social network [18]. Twitter, one of the most popular social network websites, has around 320 million users monthly as of December 31, 2015 [14]. According to Ginn, R., et. al., [5], Twitter users generate more than 9000 tweets every 4 seconds. With this volume of data, healthcare providers and agencies tried to analyzing and predicting ADRs from the content of Twitter using data mining techniques [10]. Yet, this approach lack the FDA four criteria as a requirement to accept ADR reports based on social network data mining, specifically: 1. An identifiable patient which is the patient information that includes patient name, or patient identification number; 2. An identifiable reporter which is the person who is in charge of reporting to the FDA such as a family member, doctor, or pharmacist; 3. The drug name that causes the ADR; 4. An adverse event or fatal outcome that caused by the drug [4].

3 Theoretical Foundation

The theoretical foundation of this study draws upon Media Richness Theory (MRT), developed by Richard L. Daft and Robert H. Lengel in the 1980's [13]. MRT categorized different levels of communication media to carry information, ranging from low (or lean) richness to high (or full) richness [13]. For instance, within a hospital setting, a lower level communication media channel between doctor and patient would be letters, reports, and emails, while a higher richness level of communication that provides rapid response and feedback channels are vehicles such as face-to-face communications and videoconferencing [13].

The MRT provides a theoretical basis for the propose tool (EZ-R). In fact, in this study, the MRT inspired the researchers to build an artifact considering the communication aspect between the doctor and the patient. Such an artifact that will mediate the ADR reporting process and improve the current passive low richness method into a richer, and more active method. It also facilitates more instant feedback between the patient and the health professional. Therefore, MRT grounded this research and inspired the design process in applying features such as chat feature (instant messaging) and other features that allow bi-directionally real-time communication between the two parties to facilitate an immediate feedback capability.

4 Research Approach

This research follows the Design Science Research (DSR) approach, introduced by Hevner and Chatterjee [7], which includes a set of artifacts that solves a wicked problem. DSR is composed of three related cycles: "the relevance cycle, the rigor cycle, and the design cycle" [7]. The relevance cycle utilization is to connect the requirements from the environment related to the research. The rigor cycle provides the prior knowledge as a foundation to the research as well as helps to add a new knowledge from the research to the knowledge base. The design cycle contributes as the construction and evaluation phase of the artifacts. Moreover, the DSR artifact outcome can be one or more namely, *constructs* which include vocabulary and symbols; *models* which include abstractions or representations; *methods* which include algorithms or practices; *instantiations* which include implemented or prototype systems; or *design better theories* [7].

Therefore, based on the DSR approach, the goal of this research is to define the problem and develop an artifact that can provides a reliable solution as a communication channel between patients and health professionals, and ultimately improve ADR reporting. Thus, the outcome solution consists of three main artifacts: a patient mobile application (instantiation), a doctor mobile application (instantiation), and an algorithm (method) that run in the backend of both applications.

5 Designing & Building the Artifacts

5.1 Technical Requirements

To develop the applications, android studio was used to implement both doctor and patient applications. The following tools were used during the development phase: android Software Development Kit (SDK), Java, Android Mobile OS, Twitter API, MySQL database, and JSON (JavaScript Object Notation).

5.2 Design & Build the Artifacts

From DSR perspectives, each of the artifacts designed to play a different role in reporting ADR namely, Dashboard (doctor's application), Mobile Application (patient's application), and an algorithm to looks up and detects side effects in patient tweets (both patients and doctor applications). The three artifacts have been designed and developed in iteration process. Both applications and algorithm have been constructed and tested to build the final artifacts. The source of the data was from Drugs.com and collected based on the top 20 drug names and the relevant 700 side effect terms, that being looked up on searches engines. This collected data have been stored on databased on the server. This sample have been used to test both applications and algorithm functionality.

The EZ-R works under two assumptions. First, the research team assumes that the doctor has a list of patients' Twitter usernames. Another assumption is that the patient agreed that all of their tweets will be monitored by the doctor. Each doctor will have an application that works as a dashboard. The next sections will describe both applications in detail.

5.3 Artifact 1: Doctor Dashboard Application (Instantiation)

In this dashboard, the home page contains the main functions which are "View Report", "Lookup for Patient on Twitter", "Chat with Patient", and "Send SMS to Patient". These functions empower doctors to help their patients to report the side effects. With taking into consideration of the previous assumptions, the doctor will use the "lookup for patients" function, which runs the algorithm to find out whether or not the patient's tweets contain mention of side effects. If the algorithm found that the patient's tweets contain a side effect, then the doctor's screen will shows this side effect. Next, the doctor can initially use "Send SMS" function to send an SMS to the patient to download the patient application on his/her smartphone. After the patient downloads the application, then the doctor will be able to use the following functions: the "View Report" function shows a list of reports or questions that are submitted by the patient. The "Chat with Patient" function enables the patient and doctor to communicate over messaging with each other. Thus, the doctor application can help doctors to monitor his/her patient on social network and empower them to help patients to report the side effects.

5.4 Artifact 2: Patient Mobile Application (Instantiation)

Initially, when the user runs the application for the first time, a login screen will be displayed. A username and password screen prompts for authentication. The user will provide unique username and password for the first time. If the username is correct, then the application will store the username on the server. If the patient tweeted about a drug side effect, the application gathers the tweet content using Twitter API. The API matches keywords in Tweets to those that are pre-stored on the server. If the tweet matches, then the application will automatically send a notification prompting the patient to report the side effect to the doctor. The patient can use the following three functions. One function is the "patient profile", which will allow the patient to enter and update his/her demographic information, address and medical record number. Another function is "send report" which helps patients report an ADR. In this function, the patient will be directed through workflow steps to complete an ADR report including patient identity, drug reactions, adverse drug event, drug name, and drug dosage. Last function is the "chat with a doctor" which allows doctors and patients to engage in a real-time transmission of text-based conversation. Thus, the patient can ask the doctor questions about completing the ADR report process, or how to avoid dangerous adverse drug reactions. Therefore, the patient application can help the patient communicate with his/her doctor any time, and to report the side effects easily.

5.5 Artifact 3: An algorithm to look up and detect side effects in patient tweets

The algorithm works in both the doctor dashboard application and the patient mobile application. The algorithm runs as a loop to detect patient tweets contains side effects that match the list of terms of side effect and drugs' names that stored previously on the server. The algorithm runs on the doctor application only when the doctor uses "lookup for patients". The following steps explain the algorithm:

(a) Algorithm Steps in Doctor Application.

(i) **Assumption:** It is assumed that the patient posted a tweet that has a side effect (Fig.2). For example, if a patient posts a tweet including this text: "I have chest pain for 2 days from using XYZ … etc.", then the application works according to the following algorithm description.

(ii) Algorithm description:

1. The doctor looks up the patient username (Fig.1 and Fig. 2).
2. The application checks if this username has tweeted about a side effect.
3. If yes, the application retrieves the tweet content using Twitter API.
4. The application compares the KeywordMatch with tweet content with side effects that are pre-stored in the server.
5. If keyword is matching, then a message is sent to the doctor about side effect (Fig.1 and Fig. 2).
6. The doctor sends SMS to patient to download the app.

(iii) **Pseudo code explain the algorithm in doctor application:**

```
{     SET         initial username
    IF (username == True) THEN { get Tweet_Content from Twitter API
        IF (Tweet_Content == True))
 THEN   { KeywordMatch ==  Tweet_Content
          Run_Function (Send SMS)     }
        ELSE REPEAT }

   ELSE     END }
```

(b) **Algorithm Steps in Patient Application**.

(i) **Assumption:** It is assumed that the patient is using his/her Twitter account using Twitter on desktop, or Twitter app on a smart device.

(ii) Algorithm description:

1. After the user logs into the mobile application, the application checks the username. (The application stores the username on the server when the user uses the patient application for the first time).
2. The application monitors tweet content that is posted on the user account (Fig.1 and Fig. 2).
3. The application gets the patient tweet content using Twitter API. (Works as a repeated process each time of tweet).
4. The application compares keywords of tweet content to side effects that are pre-stored on server.
5. If KeywordMatch matches one of side effect that pre-stored on server.
6. Then automatically send a push notification to patient (Fig.1 and Fig. 2).
7. Patient will use the mobile app to report his/her side effect.
8. Doctor will receive the report (Fig.1 and Fig. 2).

(iii) **Pseudo code explain the algorithm in patient application:**

```
{
   Get username From Server
   IF (username == True) THEN { get Tweet_Content from Twitter API
   IF (Tweet_Content == True)) THEN { KeywordMatch == Tweet_Content
Run_Function (Push_Notification)
IF Push_Notification == is_open
 {initiate_Patient_App
 }
       }
ELSE REPEAT
}
   ELSE    END

}
```

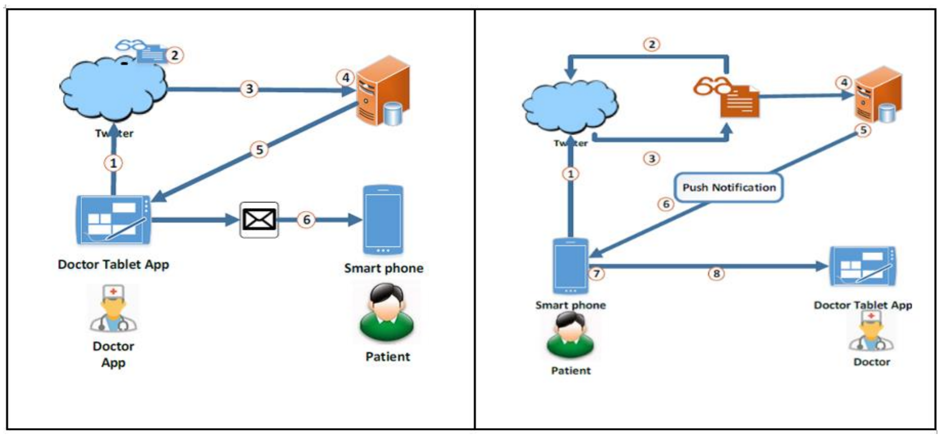

Fig. 1. Algorithm steps of both doctor application (left) and patient application (right).

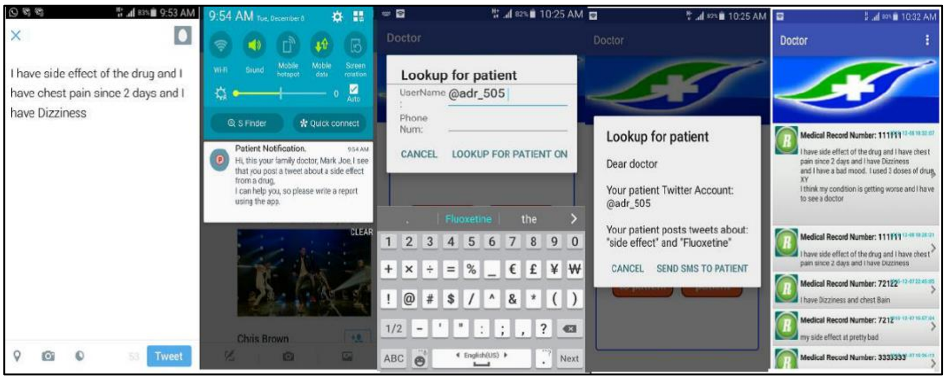

Fig. 2. Screenshot of both doctor and patient applications.

6 Novelty and Advantages

The artifact, EZ-R is a reporting application that will rely on Twitter and works as a mediating solution that will fulfills the FDA's criteria and helps alleviate the current process limitations. EZ-R helps the user to ADR reporting in real time after he/she posts a tweet. In addition to the uniqueness of using EZ-R application, it also has two advantages. These advantages are: first, it creates an active channel between the patient and his/her doctor. Second, obtains the four information to validate an ADR report assigned by the FDA. On the other hand, EZ-R is a different solution from the data mining or machine learning solutions because data mining and machine learning solutions are required a huge amount of data that need data cleansing which can be time-consuming, costly, and require special data analytical skills [10]. Moreover, data mining and machine learning solutions don't provide a communication tool between the patient and the health professionals in terms of reporting ADRs from Twitter.

7 Limitation and Challenges

For this pilot study, the researchers examined the functionality of the application, however, there were some challenges and limitations. First, the researchers were limited in detecting false-positives to detect synonyms of symptoms of the side effect that not stored. Second, there remains a limitation in regard of misspelled words, unknown keywords, or incorrect drug names submitted by patients and were not previously stored on the server.

8 Conclusion and Future Work

Recently, a large number of patients discuss their health issues and ADRs on different social networks [18], such as Twitter, which leave a large percentage of ADRs not reported to authorize health professionals or to the Food and Drug Administration (FDA) [18]. So far there is no reliable tool that might be used by health professionals to report an ADR based on their patient's tweets. This research provides a reliable solution that targeted patients whom discussing their current health condition on Twitter, and facilitates the submission of ADR by improving the communication with their health care professionals more easy and user-friendly.

Future enhancement should take into account the aforementioned limitations, as well as provide a sufficient sample size for the evaluation. Moreover, this solution might incorporate video conferencing within the application. More importantly, the application can be connected with the FDA database. Also, this solution could be integrated with other technologies, such as WordNet, to detect unknown symptoms or unidentifiable patients from different social networks. Lastly, a proper HIPPA and security procedures should be implemented to deal with patient's data privacy.

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