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On the Use of Sensors in Mental Healthcare

Nidal DRISSI [a,1], Sofia OUHBI [b], Mohammed ABDOU JANATI IDRISSI [a], Mohamed EL KOUTBI [a] and Mounir GHOGHO [c]

[a] *ENSIAS, Mohammed V University in Rabat, Morocco.*
[b] *Dept of Computer Science & Software Engineering, CIT, UAE University, Al Ain, UAE.*
[c] *Université Internationale de Rabat, Rabat, Morocco.*

Abstract. The use of connected health solutions in the diagnosis and the monitoring of mental health issues is a promising field. However, in order for the connected mental health solutions to be effective, accurate data about the patient's mental and physical state is required. Sensors can therefore be very helpful instruments to provide patient's data needed for a good diagnosis and monitoring. This paper conducts a literature survey to present the current research involving connected health solutions using sensors in the treatment of mental health. Seventeen papers are selected following a search protocol and analyzed to present the publication trend of research on sensors used for mental health and to identify their research types and contribution types. This study may assist researchers interested in the use of sensors for mental health care, as it can serve as a starting point presenting an overview of the addressed topics and the weak areas of the research. The study may also assist patients and clinicians interested in the field to have an overview of the proposed solutions and uses of sensors in mental health care.

Keywords. sensors, mental health, connected health, review

1. Introduction

Mental health is a crucial aspect of the general health. There is no stable health without a stable mental health [1]. Mental illnesses constitute an important part of the global burden of disease, and are becoming a more serious threat over time [2]. Evidence suggests that good communication between clinicians and patients is particularly important in mental healthcare in which diagnostic procedures are based on verbal communication rather than on physical and objective examinations [3, 4]. Connected health can support effective communication between the patient and the clinician [5].

Connected mental health or e-mental health is an aspect of healthcare that introduces the use of Information and Communication Technologies (ICT) solutions in mental healthcare. Connected health services contribute to the improvement of the mental healthcare domain by helping in the diagnosis and detection of mental illnesses [6] as well as the monitoring of people in problematic situations [7]. Connected mental health

[1] Corresponding Author. E-mail: drissi.nidal@gmail.com

brings a number of solutions that can make dealing with mental problems easier [8], such as: tele-mental health, electronic health records (EHRs), and mobile mental health solutions [9]. With the use of ICT, more data about patients can be collected, and new measures can be used to estimate the patient's state [10]. The use of sensors in the collection of data is therefore a helpful approach to provide the needed patient's information.

Sensors can provide accurate, momentary and continuous data about patients, which can help in the early detection and prevention of mental illnesses as well as the real-time monitoring of patients [11]. Many types of sensors can be incorporated in the mental healthcare process. Data can be collected from smartphones using their integrated sensors [12], wearable devices or on-body sensors like eye tracking devices [13] or wrist sensors [14], positioning sensors and magnetic sensors for indoor collect of data [15]. This paper presents a survey of literature to give an overview of the research that addresses the use of sensors in the mental healthcare industry. Seventeen papers have been selected according to inclusion and exclusion criteria and were analyzed to capture their main contribution. This study provides an overview of addressed topics and weak areas of the research, as well as the proposed solutions and uses of sensors in mental health care, which may be helpful for researchers, clinicians and patients.

2. Method

This study is a survey of literature of articles that address the topics of use of sensors in the mental healthcare domain.

2.1. Review and Protocols

The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) [16] statement for reporting systematic reviews and Meta-Analyses guidelines were followed on the construction of this study.

2.2. Search strategy

To identify papers to be included in this study, a search has been conducted in January 2019 in the following sources: Science Direct, IEEE Xplore Digital Library, Springer Link, Wiley Online Library, ACM Digital Library, and Google Scholar. The search in these digital libraries was based on the following search strings:

- (Electronic OR Connected) AND Mental AND Health.
- (e-Mental OR eMental) AND Health.
- Mental and (eHealth OR e-Health).

2.3. Study selection

The inclusion criteria were limited to the studies that address the topics of connected health for mental health issues. The studies that met at least one of the following exclusion criteria (EC) were excluded:

- EC1: Studies that do not address the use of sensors in mental healthcare.

- EC2: Studies that do not focus on the topic of mental health but rather focus on the general health.

The selection of these search strings serves the purpose of this study, as the authors wanted to construct a global view of the topics of use of ICT in the healthcare domain. The search was based on the title, the abstract and key words. A total of 17 papers were selected out of 210 papers identified. Fig. 1 shows the process of the papers selection.

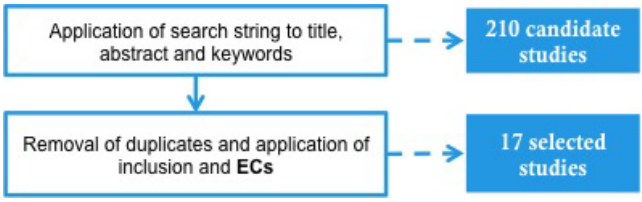

Figure 1. Selection results *Acronym. EC: Exclusion Criteria*

2.4. Data extraction strategy

The selected papers have been classified based on their research type, contribution type and empirical type [17]. The research types can be classified as follows: (i) solution proposal: all papers that represent new or evolved solutions and approaches for the use of sensors in mental healthcare; (ii) review: reviews of the existing literature on the use of sensors in mental healthcare; or (iii) other. The contribution types can be classified as: (i) model: representation of a system that illustrates the use of sensors in mental healthcare through a defined structure; (ii) tool based techniques: A technique that can be based on software like an application or hardware like a device; (iii) method: a specific procedure to use sensors in mental healthcare; or (iv) other. The studies could be empirically validated using one of the following methods: (i) experiment: examining an approach in a controlled environment under controlled conditions; (ii) case study: examining an approach in real life; (iii) theory: all studies that were not empirically validated were considered as theories; or (iv) other.

3. Results

3.1. Classification results

Table 1 presents the overall results of this literature survey. Fig. 2 presents the publication trend of the selected papers.

The interest on using sensors in the mental healthcare domain started since the late 90s, but it did not receive continuous attention and started to be an active aspect in the research until 2010, as Fig. 2 shows.

Fig. 3 presents the publication channels of the selected papers. 71% of the selected papers have been published in conferences while 29% were published in journals.

Fig. 4 presents the research types identified in the selected papers about the use of sensors in mental healthcare. The majority of the papers were identified as solution proposals.

Table 1. Results

Ref.	P. Year	P. Channel	Research type	Empirical type	Contribution type	Contribution topic
[15]	1998	Conference	Solution proposal	Case study	Model	Monitoring solutions
[18]	2006	Conference	Solution proposal	Theory	Model	Bio signals
[19]	2010	Conference	Solution proposal	Theory	Tool-based technique	Wearable sensors
[20]	2011	Journal	Solution proposal	Experiment	Tool-based technique	Mobile solutions
[21]	2011	Conference	Solution proposal	Theory	Model	Wearable sensors
[13]	2012	Journal	Review	Theory	Method	Wearable sensors
[14]	2013	Conference	Solution proposal	Experiment	Model	Wearable sensors
[22]	2014	Conference	Solution proposal	Theory	Model	Monitoring solutions
[23]	2014	Conference	Solution proposal	Case study	Model	Monitoring solutions
[24]	2015	Conference	Review	Theory	Tool-based technique	The IoT and cloud-based processing
[25]	2015	Conference	Solution proposal	Experiment	Model	Wearable sensors
[26]	2016	Conference	Review	Case study	Tool-based technique	Smart Home and Ambient Assisted Living
[27]	2016	Conference	Solution proposal	Theory	Tool-based technique	Brainwaves detection
[28]	2016	Conference	Solution proposal	Case study	Model	Mobile solutions
[12]	2017	Journal	Review	Theory	Method	Mobile solutions
[29]	2017	Journal	Review	Theory	Model	Ubiquitous sensors
[11]	2018	Journal	Review	Theory	Tool-based technique	Monitoring solutions

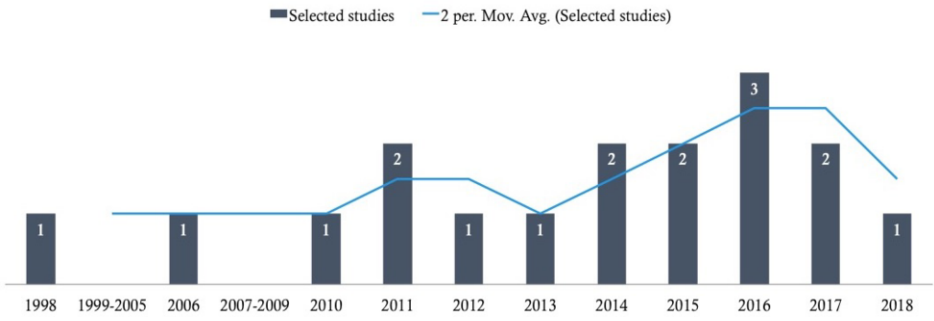

Figure 2. Publication trend

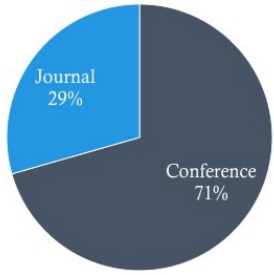

Figure 3. Publication channels

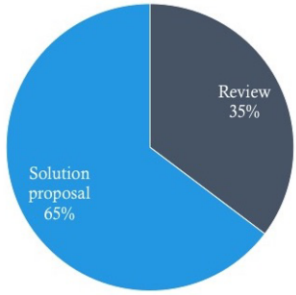

Figure 4. Research types of the selected papers

Fig. 5 presents the contribution types identified in the selected papers in this survey. Most of the papers selected present models that illustrate how sensors can be used in the mental healthcare domain.

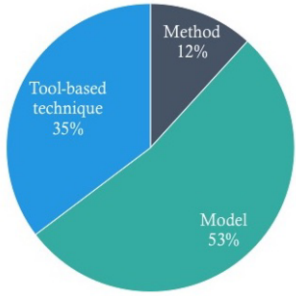

Figure 5. Contribution types of the selected papers

Most of the studies were not empirically validated and were represented as theories, only seven of the selected studies were empirically validated, three as experiments and four as case studies.

3.2. Proposed solutions for using sensors in mental healthcare

3.2.1. Solutions for wearable sensors

Fletcher et al. [19], have presented wearable sensors for electro dermal activity (EDA) and mobile plethysmography, in addition to mobile phones and the supporting wireless network architecture. Wijsman et al. [21] have proposed a wearable sensor system to measure physiological signals like electrocardiogram (ECG), respiration, skin conductance, and electromyography (EMG) of the trapezius muscles, to detect mental stress. Seven principal components were calculated from the measured signals, then used with classifiers to detect stress or non stress conditions. Almost 80% accuracy was found. Sano and Picard [14] have represented a model where they collected data using wrist sensors, mobile phones and surveys, then identified features associated with stress, and used machine learning to classify stress or no stress cases. The results showed over 75% accuracy. Sano at al. [25] have identified factors, from data collected via wearable sensors, that affect the academic performance of the person, then using feature selection and machine learning they have found an association between the analyzed factors and personality types. Classifications accuracy using data collected from mobile phones and the wearable sensors ranked from 67% to 92%.

3.2.2. Monitoring systems

Yamaguchi et al. [15] have presented an indoor monitoring system based on infrared poisoning sensors and magnetic sensors, in order to monitor the human activity and behavior. Butca et al. [22] have proposed an experimental model for monitoring environmental parameters connected to a cloud platform that aggregates data received from the sensors (e.g. body temperature, humidity from the air). The data is gathered and available for further processing. Palmius et al. [23] have proposed a multi-sensor and smartphone based system that allows remote real time monitoring of psychiatric patients symptoms.

3.2.3. Mobile solutions

Burns et al. [20] have developed a mobile phone application *Mobilyze* and a supporting architecture which they believe to be the first ecological momentary intervention for unipolar depression, in which machine learning models predict patients' mood, emotions, cognitive/motivational states, activities, environmental context, and social context based on phone sensor values (e.g. Recent calls, global positioning system, ambient light). Promising accuracy rates were achieved for predicting categorical contextual states (e.g. Location), from 60% to 91%. For states rated on scales (e.g. Mood) the predictive capability was poor. Farhan et al. [28] have presented a multi view bi-clustering algorithm which takes multiple views of smartphone sensing data as input to identify homogeneous behavioral groups and the key sensing features that characterize the different groups. They have then employed the key sensing features that distinguish the groups to create predictive models to predict the group assignment of individuals. The generalizability of the models was verified using the support vector machine classifier. Validation studies showed that the classifiers could classify individuals in the right group with an accuracy of 87%.

3.2.4. Other solutions

Jung and Lee [18] have proposed a system that measures bio signals (PPG, SKT, GSR) using sensors which analyzes the mental health then supports an appropriate service to reduce stress and melancholy. The system relates on Bluetooth for WBAN (Wireless Body Area Network) communication. The communication between the bio signal measurement module and the PDA (Personal Digital Assistant) showed an inefficiency, as a solution they have proposed a method to shorten the WBAN connection time. Sahu and Sharma [27] have proposed a system that consists of two parts: 1) a device to correctly detect and categorize the types of brainwaves and the eye movements, then transfer the data to the software part of the system. 2) a LabVIEW software to monitor the components of the brain waves. Mohr et al. [29] have provided a layered, hierarchical model for translating raw sensor data into markers of behaviors and states related to mental health.

4. Discussion

4.1. Main findings

The interest on the use of sensors in mental healthcare started in late 90s but it was not until 2010 that this topic has received a continuous attention from researchers. This could be explained by the improvement of technologies and the ability to use sensors in a more efficient way. The majority of studies were published in conferences, and the majority of the contribution types were models. Few studies were empirically validated, which reveals there is a need of more empirical evaluation in this field of research.

Table 2 presents a list of expected topics to be addressed by literature on the use of sensors, their motivation, and the selected articles that discuss these aspects.

Accuracy is an important aspect that was taken into account by 5 of the selected papers, but all 5 articles considered the general accuracy of the whole system not the accuracy of the data generated by sensor and if it is accurate enough to be used, research studying the accuracy and preciseness of the collected data is needed.

Security and confidentiality are important attributes while collecting and transferring health data, 3 of the selected papers mention security aspects related to data exchange in their study. Research focusing on security challenges and solutions of mental health systems using sensors is needed.

Even tough costs and affordability are important aspects, none of selected papers addresses them. Research invoking these aspects is desired.

The use of sensors may generate technical problems in mental health systems. Only three studies addressed some technical issues: [18] presented a solution to slow connectivity between the sensor and the other parts of the system; [24] addressed storage and energy issues; and [19] addressed connectivity and power consumption issues.

Although patients perspective and acceptance are critical to the success of mental health systems, only one study [11] mentioned the user engagement issues. Patients are the ones wearing and using the sensors, their engagement and comfort are crucial for an effective use of sensors. Research on mental health users acceptance and engagement is needed.

Even tough clinicians perspective on the use of sensors is important and may help improve the filed, none of the selected papers addressed this aspect.

Table 2. Important topics

Topic	Importance	Articles
Accuracy	The accuracy of the results obtained by systems that rely on sensors for the collect of data. Accuracy and preciseness of results are very critical and important while making medical decisions.	[14, 20, 21, 25, 28]
Security	Security and confidentiality while collecting and transferring the patient's data is a very important aspect, as health data are sensitive and personal information.	[11, 24, 29]
Costs	Use of sensors to collect data requires inclusion of multiple parts, like a hardware (The sensor), a connectivity system, a storage unit, etc. The use of sensors may end up being very costly.	-
Affordability	Based on the costs, could patients afford having a sensor as a part of there treatment process?	-
Technical issues	Use of sensors may introduce technical problems, that might limit there use and effectiveness.	[18, 19, 24]
Patients perspective	Patients perspective, acceptance and engagement in systems with sensors are important aspects that need to be addressed, as it may reveal issues that need to be solved for a better patient experience.	[11]
Clinicians perspective	Clinicians perspective on the use of sensors, needs to be studied and taken into account while developing medical solutions that use sensors, as it may help improve and bring new solutions to the field.	-
Guidelines of use	Rules, instructions and guidelines on the use of sensors are important, as they provide a general, efficient and structured way for using sensors.	-

None of the selected papers have presented guidelines or frameworks, which points to the lack of literature that proposes general and structured ways to exploit sensors in the mental healthcare domain.

4.2. Implications

This study may have implications for researchers who intend conducting studies on the use of sensors in mental healthcare as it provides an overview of related literature, solutions proposed, their limitations and suggestions for future areas of research. We invite interested researchers to conduct their research more towards the mentioned gaps on the literature, in order to increase the quality of research in this topic. More attention should be given to technical and accuracy problems of the use of sensors, security aspects, studying patients and clinicians perspectives on the use of sensors, validating the proposed solutions, addressing costs and affordability issues, and proposing guidelines, rules and structured methods to the use of sensors in mental healthcare.

4.3. Limitations

This study focuses on 17 papers selected using general search strings about connected mental health. More papers could be found using more specific search strings. The selection was limited to the title, the abstract and the key words, which may have impacted the final list of relevant studies. PubMed digital library was not included in the search sources which may have impacted the number of papers identified. However, as the search was focused more on the engineering aspect of the topic not the medical aspect, we think that this had a limited impact of our selection.

5. Conclusion and future work

This study presents a survey on studies that address the use of sensors in the mental healthcare domain. The selected papers were classified based on their research type, contribution type and empirical type. Then we presented a brief description of the proposed solutions. We identified the need to conduct more research on technical problems associated with the use of sensors, empirically validating the proposed solution, address the security, accuracy, cost and affordability problems, and the need to conduct studies on the patients and clinicians perspectives on the use of sensors for the collect of data. The topic of use of sensors in the healthcare domain is a topic that still in its infancy and presents a big opportunity for developing efficient, accurate, and more advanced mental health inventions.

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