A review about Technology in mental health sensing and assessment

Thierry Jossou[1,2*], *Daton* Medenou[2], *Aziz* Et-tahir[1], *Héribert* Ahouandjinou[2], *Thierry* Edoh[3], *Roland* Houessouvo[2] and *Leandro* Pecchia[4]

[1]Materials, Energy, Acoustics Team, High School of Technology of Sale, Mohammed V University of Rabat, Morocco
[2]Department of Biomedical Engineering, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, Benin
[3]Institute of Pharmacy, Department of Drug Regulation Affairs, RFW-University of Bonn, Bonn Germany
[4]School of Engineering, University of Warwick, Coventry, CV4 7AL, UK

Abstract. Information and communication technologies (ICT) such as smart devices, the Internet of Things and wireless sensor networks are gradually being introduced into the health system for early diagnosis and management of certain diseases. The state of the art of the use of these technologies in mental health identified 37 articles published in indexed high impact journals in the period 2003-2021. The snowball sampling method was used to select these papers. From this literature review, it appears that several of these technologies are used to support the early detection of mental disorders. Various systems based on wearable sensor networks, the Internet of Things and pervasive and ubiquitous computing have been designed and implemented in this sense. However, most of the applications are designed for academic purposes. 29% of the papers deal with the use of mobile technology in the detection of mental illness, while 67% have studied other technologies such as wearable sensor networks. 4% of the papers concern the use of web platforms in the detection and assessment of mental health disorders.

1 Background

Mental health sensing and assessment for early detection, prevention, and prediction of mental diseases and disorder are becoming one of the top research topics in health informatics. Sensing, predicting, and early detecting mental disorders as well as social isolation are increasingly taking benefit from (Wireless) Sensor Networks Technologies and systems as well as from Body Area Networks.

The results of a survey on mental health monitoring were presented by Enrique Garcia-Ceja et al [1]. They found that "mental states can be manifested by physiological and behavioral changes". Furthermore, they defined mental health as problems common worldwide, including changes in mood, personality, inability to cope with daily problems or stress, withdrawal from friends and activities.

This shows how mental health can socially isolate sufferers. All age groups can suffer from mental disorders. For example, children and adolescents mental disorders account for 13.4% of mental illnesses worldwide. The global prevalence of anxiety disorders was 6.5%, 2.6% for depressive disorders, 3.4% for attention-deficit hyperactivity disorder and 5.7% for disruptive disorders [2].

The main objectives of this literature review are to determine the extent to which technology supports mental health. It also presents the problems encountered and future challenges in terms of mental disorders' assessment and detection in this digital age.

2 Methodology and data

Articles published from 2003 to 2021 in the field of mental health were retrieved through search engines such as Google Scholar and scientific databases such as PubMed, Wiley, NCBI, IEEE Xplore, Scopus and Web of Science. The search string included terms such as "mental disorder" and "sensors" and "ICT". With the key words: APP, mobile Application, telemedicine, smartphone application, Internet of Thing, being considered under the acronym ICT. And the DSM-5 as a reference document for the different mental disorders concerned. At the end of this first search 100 articles with full text in English were found. Then snowball sampling was applied to the references of these articles. And another 137 new articles with full text in English were found.

Articles titles, abstract and texts (if needed) were screened by two authors independently against the inclusion criteria. A third overviewed the process and solved any issue arising in the process. The inclusion criteria were: mental health; mental disorders and diseases; technology enabled sensing; assessment methodologies etc.

Then, the articles' classification according to the subject, matter and the technology or the assessment

* Corresponding author: thierry.jossou@gmail.com

method used, was made. Thus, 200 inappropriate papers were excluded and all the 37 included works were analyzed in order to provide a state of the art according to four subsections namely: Depressive Disorders/Major Depressive Disorder (MDD), Bipolar disorder (BD), Attention-deficit/hyperactivity disorder (ADHD), Dementia and Information and Communication Technology (ICT), Autism Spectrum Disorders, Early Detection of mental Illness, Affective Illness, Autonomy Loss, Schizophrenia and Parkinson's Disease (PD).

3 Results

The literature review (summarised in Table 1) revealed that sensors and ICT-based solutions are increasingly used to manage, assess and detect mental illness. However, their use is more important in other medical fields such as physical healthcare [3]. Therefore, this study reviewed existing and ongoing projects dealing with the detection of mental disorders and mental health-related illnesses. In addition, it provided an understanding of the impact of mental disorders on the behaviour of individuals suffering from them [4].

Table 1. Summary of the literature review.

Authors Pub. Year	Enabling Technology	Type of study
Jovanov et al., 2003	Wireless Sensors Networks	Cross-sectional
Gaggioli et al., 2011	Mobile phone platform, Windows mobile, open source	Cross-sectional
Guevara et al., 2011	Acceleration and voice intensity sensors	Cross-sectional
Grunerbl et al., 2014	Smartphone-sensing	Cross-sectional
Muaremi et al., 2014	Wearable devices	Cross-sectional
Palmius et al., 2014	Smartphone	RCT
Applin et al., 2015	IoT, sensors	None
Osmani et al., 2015	Smartphones	Cross-sectional
Zhou et al., 2015	Ubiquitous sensors	Case-control
Abdullah et al., 2016	Smartphones App. (MoodRhythm)	Cross-sectional
Coelho et al., 2016	Wearable sensors	None
Farhan et al., 2016a	Smartphone sensing data	Cross-sectional
Farhan et al., 2016b	Smartphone sensing data	None
Ferreira et al., 2016	Ubiquitous Mobile Instrumentation	None
Galan-mena et al., 2016	Semantic web, mobile tools and robotic assistants, intelligent ICT	Cross-sectional
Gros et al., 2016	ICT	Cross-sectional
Ibrahim et al., 2016	Application of ICT tools	None
Matthews et al., 2016	Smartphone sensors, smartphone application	None
Maxhuni et al., 2016	information from smartphones	Cross-sectional
Robles-Bykbaev et al., 2016	ICT, Data mining	None
Sarker et al., 2016	Mobile sensor	Cross-sectional
Tanaka et al., 2016	Simulation	RCT
Wang et al., 2016	Smartphone	Randomized control trial
Chong et al., 2017	Sensors, IoT	Cross-sectional
Cook et al., 2017	Polysomnography, Wrist-worn actigraphy	Cross-sectional
David et al., 2017	ICT	Qualitative
Odette Frundt et al., 2017	Quantitative sensory testing	Cross-sectional
Kim et al., 2017	Passive Infra-Red (PIR) motion sensors	None
Place et al., 2017	Mobile sensing platform	Cross-sectional
Yoo et al., 2017	Biosensor, IoT	None
Airehrour et al., 2017	Task reminders, video and picture, speech system	None
Asuroglu et al., 2017	Sensors (foot-worn sensors.)	None
Teipel et al., 2018	ICT, Algorithm	RCT
Wang et al., 2018	Smartphones and Wearable sensor	Cross-sectional

Authors Pub. Year	Enabling Technology	Type of study
Gladstone et al., 2020	CATCH-IT and online HE	Randomized clinical trial
Debard et al., 2020	Wearable sensors, online Platform	None
Lahti et al., 2021	Wearable sensors	observational

3.1 Depressive Disorders / Major Depressive Disorders (MDD)

ICT-based solutions for the early detection and monitoring of depression have been investigated in [5, 6], in order to reduce misinterpretation of the diagnosis. To this end in [5], a wristband was designed using ICT for daily data collection and analysis from depressed patients. A mobile detection solution to assess students' mental health, has also been proposed in view of the depression rate increasing on university campuses.

3.2 Bipolar Disorder (BD)

Bipolar disorder (BD) is a serious mental illness that affects 2.6% of the US population aged 18 years and older per year. As rhythmicity is a key component of well-being in bipolar disorder, it has been assessed using smartphones for automatic detection [7]. Dynamic psychological processes (bipolar disorder) are most often assessed using self-report instruments [8, 9]. Their limitations have been assessed through the use of smartphone sensors, in which clinically validated treatments have been previously incorporated, as an acquisition system [8]. However, the status of patients with bipolar disorder can be classified using information collected by Smartphones [10].

3.3 Attention-deficit / hyperactivity disorder (ADHD)

According to [11], ICTs are used to establish diagnosis and monitoring of students between 6-18 years old with Attention-deficit/hyperactivity disorder (ADHD). Advanced ICT tool as Gordon Diagnostic System (GDS) has been used for assessment and diagnosis. And Learning Management System (LMS) has been used to address special need of students with ADHD learning abilities and preferences. However, other ICT solutions for ADHD students helping exist such as: online learning and augmented reality based education. But, more research is needed to evaluate the different proposed solutions.

3.4 Dementia and ICT

According to [12], UN statistics show that our society is ageing rapidly, leading to an assistive technologies development increasing, for people with dementia.

Policy makers (politicians and governments) are concerned about the contribution of technology to the effective management of people with dementia. Cognitive function is an important endpoint of treatment in clinical trials for dementia. However, the measurement of cognitive function by standardized tests is biased by highly constrained environments (such as hospitals) [13]. ICT solutions for mental health improve the quality of life of older people with dementia and support health care for dementia patients. Intelligent assistive technologies (IATs) can offer innovative solutions to mitigate the global burden of dementia and provide new tools for dementia care.

3.5 Autism spectrum disorders

According to World Health Organization (WHO), 1 of 160 persons in the world is diagnosed with Autism Spectrum Disorders (ASDs). However, in low-and middle-income countries (LMIC), the prevalence of ASDs is partially unknown or properly investigated.

The review pointed out a series of ongoing projects or already archived. For example, in [14, 15], the authors worked on a project to discover the link between avoidant personality disorders (APD) and, physical and psychological stress. A test was conducted on two samples, one composed of patients with avoidant personality disorders and the other of healthy people.

3.6 Early detection of mental illness

Machine learning techniques have greatly contributed to the development of tools to assist doctors in mental disorders prediction, in particular anxiety disorders. The study reported in [16] concerns the early detection of mental health changes in individuals by combining passive smartphone sensors with the CrossCheck method. In this case, the disease of schizophrenia is concerned. Many other ICT-based tools have been used for early assessment of other mental illnesses, such as wireless sensor networks (stress), wearable biosensors (bipolar disorder), mobile phone platforms (stress and physiological arousal) [17], acceleration and voice intensity sensors (behaviour and correlation with mental health), smartphone sensing (bipolar disorder, depression), semantic web (autism), etc.

3.7 Affective illness

Affective disorders are frequently encountered among elderly populations. Sleep disturbance is a common and important component of affective illness. The SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis method was used to measure ICT impact on affective disorders' diagnosis in older people. The idea was to see if there would be any added value in using these techniques in addition to traditional clinical diagnostic methods. It was found that ICT offers interesting tools for affective disorders diagnosis and management, but seems to be poorly known by practitioners and future users [18, 19].

3.8 Autonomy loss

According to [20], the use of ICT can provide added value in frail elderly people monitoring, and could potentially contribute to reduce the risk of institutionalization. To this end, a Safe and Easy Environment (SafEE) project has been developed to improve the elderly's living conditions. It combines an ICT-based behavioral analysis platform with adapted non-pharmacological therapeutic responses. The results show that the platform has been accepted by all stakeholders [20].

3.9 Schizophrenia

Human behavior is increasingly being reflected or interpreted by sensors and ICT. This is particularly important when it comes to behavioral changes associated with severe mental illnesses, including schizophrenia [16, 21]. Passive smartphone sensors have been used to collect data from schizophrenia patients recently discharged from hospital. This was done to monitor their mental health indicators to facilitate the prediction and early management of relapse. The results show a correlation between different behavioural characteristics (sleep, mobility, conversations, smartphones use) and mental health indicators related to schizophrenia [16].

3.10 Parkinson's disease (PD)

The major cause of morbidity and mortality among patients with Parkinson's disease (PD) is the motor changes that restricting their functional independence. Therefore, monitoring the disease manifestations is crucial to detect any worsening of symptoms timely [22, 23]. To this end, wearable sensors have been attached to the feet of patients suffering from it in order to collect and analyze their physiological data. This would facilitate its better monitoring for more effective management [23].

4 Discussion

The growing ageing of the population and health care costs increasing, require a new paradigm for the world's health systems. They need to focus on the patient and put more emphasis on prevention rather than treatment [7]. In this framework, sensors and ICT are usable tools especially in the field of mental health. The diversity and lack of consensus in the emerging ICT sector is however, a strong limitation for their use in daily practice [10]. The use of information and communication technologies (ICT) could bring added value in mental illnesses' recognition and assessment [10].

According to the literature, research on ICT and sensors' applications in the field of mental health, dates from the last two decades and, for the most recent ones from the last ten years. Thus, several authors have worked on the subject from different perspectives.

Many work and techniques used were developed around projects implemented in Europe, from which some are already completed and others are ongoing. A large majority of ICT applications in mental health are based on smartphones and mobile applications [5, 24-34].

Many studies have linked human behaviour to mental health [15, 28, 35-38]. They show the close link between mental health and human behaviour. The first concern was the possibility to access the invisible world of psychiatry and psychology. However, human behaviour's study in real life was an opportunity for access. It is better than traditional meetings, and other methods such as patient-doctor screening meetings, where the patient is interviewed by the doctor. These methods have shown their limitations [39].

Since this possibility has been known, various correlations between different mental illnesses and behavioural patterns have been approached. The most discussed are: stress level, depression, loneliness, epilepsy, mood disorders etc. These are factors that influence different people in their employment, social and associative life. A better perception of ICT applications' progress in mental health has been given in [38-40]. While the future challenges are: big data processing and management, patient's data security and confidentiality.

5 Conclusion

This work allowed us to review the literature of scientific work on mental illnesses and the different technologies used to assess them. Regarding the various articles covered, ICT associated with advances in wireless sensors, portable and wearable sensors, specific applications, smartphones and IoTs allow effective assess, prediction, detection and management of mental illnesses. Researchers achieved also many correlation between mental health and patients' real life. Even if these methods give many objectives results, they may be more improve concerning their precision, security and complex imaging exams' integration as tomography and IMR. The main perspective envisaged at the end of this literature review is to perform validation tests with methods discovered in this review, by using a sample of patients from African countries especially from Benin Mental Hospital.

References

1. E. Garcia-Ceja et al., Pervasive and Mobile Computing **51**, 1–26 (2018)
2. G. V. Polanczyk, G. A. Salum, L. S. Sugaya, A. Caye, L. A.Rohde, J. Child Psychol. Psychiatry **56**, 345–365 (2015)
3. E. Jovanov *et* al., IEEE Eng. Med. Biol. Mag. **22**, 49–55 (2003)
4. A. Gaggioli et al., Pers. Ubiquit. Comput. **17**, 241–251 (2013)
5. D. Zhou et al., Tackling Mental Health by Integrating Unobtrusive Multimodal Sensing, 8

6. T. Gladstone et al., IJERPH **17**, 7736 (2020)
7. R. Wang et al., Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. **2**, 1–26 (2018)
8. M. Matthews et al., Assessment, **23**, 472–483 (2016)
9. V. Robles-Bykbaev, D. Quisi-Peralta, M. Lopez-Nores, A. Gil-Solla, J. Garcia-Duque, in 2016 International Conference on Control, Decision and Information Technologies (CoDIT), 280–285 (IEEE, 2016), doi:10.1109/CoDIT.2016.7593574
10. A. Maxhuni et al., Pervasive and Mobile Computing, **31**, 50–66 (2016)
11. M. Ibrahim, P. W. C. Prasad, A. Alsadoon, L. in 2016 13th International Joint Conference on Computer Science and Software Engineering (JCSSE), 1–6 (IEEE, 2016), doi:10.1109/JCSSE.2016.7748860
12. D. Airehrour, S. Madanian, A. M. Abraham, 6 (2018)
13. S. Teipel et al., Alzheimer's & Dementia, **14**, 1216–1231 (2018)
14. J. Galan-Mena et al., in 2016 IEEE Biennial Congress of Argentina (ARGENCON) 1–5 (IEEE, 2016). doi:10.1109/ARGENCON.2016.7585361
15. Y. Tanaka et al., Brain Behav., **6**, (2016)
16. R. Wang et al., in Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing, 886–897 (ACM, 2016), doi:10.1145/2971648.2971740
17. G. Debard et al., Journal of Sensors **2020**, 1–15 (2020)
18. A. Gros et al., Front. Aging Neurosci.**, 8**, (2016).
19. J. D. Cook, M. L. Prairie, D. T. Plante, Journal of Affective Disorders **217**, 299–305 (2017)
20. R. David et al., Alzheimer's & Dementia **13**, (2017)
21. A. C. Lahti, D. Wang, H. Pei, S. Baker, V. A. Narayan, JMIR Ment. Health **8**, e26234 (2021)
22. H. Yoo, K. Chung, Cluster Comput., **21**, 1139–1149 (2018)
23. T. Aşuroğlu, et al., Biocyb. And Biomed. Eng. **38**, 760–772 (2018)
24. A. Grunerbl et al., IEEE J. Biomed. Health Inform. **19**, 140–148 (2015)
25. Z. H. K. Chong et al., Predicting potential Alzheimer medical condition in elderly using IOT sensors - Case study. 8
26. V. Osmani, IEEE Pervasive Comput. **14**, 10–13 (2015)
27. K. Saunders et al., in Appropriate Healthcare Technologies for Low Resource Settings (AHT 2014), 4–4 (Institution of Engineering and Technology, 2014), doi:10.1049/cp.2014.0764
28. Y. L. Coelho, T. F. Bastos-Filho, IFAC-PapersOnLine**, 49**, 216–220 (2016)
29. A. Muaremi, A. Bexheti, F. Gravenhorst, B. Arnrich, G. Troster, in IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI), 185–188 (IEEE, 2014), doi:10.1109/BHI.2014.6864335
30. S. Abdullah et al., Journal of the American Medical Informatics Association**, 23**, 538–543 (2016)
31. A. A. Farhan, et al., in 2016 IEEE Wireless Health (WH), 1–8 (IEEE, 2016), doi:10.1109/WH.2016.7764553
32. A. A. Farhan et al., in 2016 IEEE First International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE), 264–273 (IEEE, 2016), doi:10.1109/CHASE.2016.27
33. D. Ferreira et al., in Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct, 608–611 (ACM, 2016), doi:10.1145/2968219.2978276
34. H. Sarker et al., in Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, 4489–4501 (ACM, 2016), doi:10.1145/2858036.2858218
35. O. Fründt et al., J. Autism Dev. Disord. **47**, 1183–1192, (2017)
36. J.-Y. Kim, N. Liu, H.-X. Tan, C.-H. Chu, IEEE Sensors J., **17**, 5694–5704 (2017)
37. S. Place et al., J. Med. Internet Res. **19**, e75 (2017)
38. J. E. Guevara, R. Onishi, H. Umemuro, K. Yano, K. Ara, Personality and Mental Health Assessment: A Sensor-Based Behavior Analysis, 6 (2011)
39. H. Haddadi, P. Healey, R. McCabe, M. Purver, Healthcare Informatics for Mental Health Recent Advances and the Outlook for the Future. 7
40. A. Muaremi, Wearable Sensing of Mental Health and Human Behavior, 1 Band (ETH Zurich, 2014), doi:10.3929/ETHZ-A-010361920