AN INTEGRATED TELEMONITORING FRAMEWORK FOR INSOMNIA DISORDER USING INTERNET OF HEALTHCARE THINGS

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A thesis submitted
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DECLARATION

I declare that this thesis entitled “An Integrated Telemonitoring Framework for Insomnia Disorder using Internet of Healthcare Things” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : Novi Azman

Date : 19/09/2022

APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : 

Supervisor Name : Prof. Dr. Mohd. Khanapi Abd. Ghani

Date : 19/09/2022

DEDICATION

I dedicate this work to my late father, Hj. Usman Bin Rakabi, and my late mother, Hj.Mardiana Binti Hj. Syech Abdulrahman, for raising me to become who I am today, and to my beloved wife, Dr. Betti Danil. Sp.A., as well as my son, Raziq Hanan Azman, for being there and supporting me all the way.

ABSTRACT

Insomnia is a health disorder caused by a disturbance in the continuity of sleep which causes serious problems for sufferers in carrying out daily activities. The prevalence of chronic insomnia sufferers is increasing in urban city life due to lifestyle and socio-economic conditions in developing countries. Currently, the de facto method to assess sleep disorder is using the Polysomnography device. However, the Polysomnography device is expensive and cumbersome, with the lack availability of device in healthcare services. This results in access limitation of treatment for the patient due to the limited number of devices. Patients in distance from health service should travel which increase time for diagnosis and high cost. Therefore, this study aims to create a solution to increase patient access to insomnia treatment. A new proposed framework could overcome problems in monitoring and diagnosing insomnia disorder. Patients at distance could receive similar performance from specialist as if they come to the hospital. In addition, this research is also proposed a diagnostic device which is portable and cheaper than polysomnography devices. The proposed device can be an alternative to the current polysomnography with low cost. The analysis in this study involves to assess user experience. This study conducted two questionnaires where the first questionnaire is to find out the current treatment conditions, constraints, and needs from the healthcare side to provide effective and efficient treatment and diagnostic for insomnia disorder. The second questionnaire was carried to find out the acceptance and user experience on the proposed framework for telemonitoring systems and its proposed devices for the diagnosis of insomnia. The second questionnaire involved eleven medical officers consisting of doctors and nurses as well as seven patients where the medical officers corresponded to the first and second questionnaires, while the patients only corresponded to the second questionnaire. The results showed that the level of acceptance from both the medical staff and the patients agreed that the telemonitoring system created by the researcher helped the treatment and provided equal access to patients for treatment and diagnosis of insomnia. The results also shows that improvement requirement on the proposed framework of the insomnia telemonitoring system by adding a platform for conducting patient consultations and a learning platform for medical staff remotely. The findings of this study indicate that the telemonitoring framework that has been studied in this study has a positive impact on all parties, both medical and patient, such that the same or even more affordable cost is the biggest concern aspect. Most patients agree on the ease of use of the device.

RANGKA KERJA SISTEM TELEPENGAWASAN BERSEPADU UNTUK PENYAKIT INSOMNIA MENGGUNAKAN INTERNET BENDA PENJAGAAN KESIHATAN

ABSTRAK

Insomnia adalah gangguan kesihatan yang disebabkan oleh gangguan kesinambungan tidur yang menyebabkan masalah serius kepada penghidap dalam menjalankan aktiviti harian. Prevalens penghidap insomnia kronik semakin meningkat dalam kehidupan bandar bandar disebabkan oleh gaya hidup dan keadaan sosio-ekonomi di negara membangun. Pada masa ini, kaedah de facto untuk menilai gangguan tidur menggunakan peranti Polisomnografi. Walau bagaimanapun, peranti Polisomnografi mahal dan menyusahkan, dengan kekurangan ketersediaan peranti dalam perkhidmatan penjagaan kesihatan. Ini mengakibatkan pengehadan akses rawatan untuk pesakit kerana bilangan peranti yang terhad. Pesakit dalam jarak jauh dari perkhidmatan kesihatan harus melakukan perjalanan yang meningkatkan masa untuk diagnosis dan kos yang tinggi. Oleh itu, kajian ini bertujuan untuk mencipta penyelesaian untuk meningkatkan akses pesakit kepada rawatan insomnia. Rangka kerja baru yang dicadangkan boleh mengatasi masalah dalam memantau dan mendiagnosis gangguan insomnia. Pesakit pada jarak jauh boleh menerima prestasi yang sama daripada pakar seolah-olah mereka datang ke hospital. Selain itu, kajian ini juga dicadangkan sebagai peranti diagnostik yang mudah alih dan lebih murah berbanding peranti polisomnografi. Peranti yang dicadangkan boleh menjadi alternatif kepada polisomnografi semasa dengan kos rendah. Analisis dalam kajian ini melibatkan untuk menilai pengalaman pengguna. Kajian ini menjalankan dua soal selidik di mana soal selidik pertama adalah untuk mengetahui keadaan rawatan semasa, kekangan, dan keperluan dari pihak penjagaan kesihatan untuk menyediakan rawatan dan diagnostik yang berkesan dan cekap bagi gangguan insomnia. Soal selidik kedua dijalankan untuk mengetahui penerimaan dan pengalaman pengguna pada rangka kerja yang dicadangkan untuk sistem telemonitoring dan peranti yang dicadangkan untuk diagnosis insomnia. Soal selidik kedua melibatkan sebelas pegawai perubatan yang terdiri daripada doktor dan jururawat serta tujuh pesakit di mana pegawai perubatan berkenaan dengan soal selidik pertama dan kedua, manakala pesakit hanya menjawab soal selidik kedua. Keputusan menunjukkan bahawa tahap penerimaan daripada kedua-dua kakitangan perubatan dan pesakit bersetuju bahawa sistem telemonitoring yang dicipta oleh penyelidik membantu rawatan dan menyediakan akses yang sama kepada pesakit untuk rawatan dan diagnosis insomnia. Keputusan juga menunjukkan bahawa keperluan penambahbaikan pada rangka kerja sistem telemonitoring insomnia yang dicadangkan dengan menambah platform untuk menjalankan perundingan pesakit dan platform pembelajaran untuk kakitangan perubatan dari jauh. Dapatan kajian ini menunjukkan bahawa rangka kerja telemonitoring yang telah dikaji dalam kajian ini memberi impak positif kepada semua pihak, sama ada perubatan mahupun pesakit, sehinggakan kos yang sama atau lebih berpatutan adalah aspek yang paling membimbangkan. Kebanyakan pesakit bersetuju dengan kemudahan penggunaan peranti.

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LIST OF SYMBOLS AND ABBREVIATIONS

µV	-	Microvolt
AASM	-	American Academy of Sleep Medicine
BMI	-	Body Mass Index
BQ	-	Berlin Questionnaire
CPAP	-	Continuous Positive Airway Pressure
EEG	-	Electroencephalography
ESS	-	Epworth Sleepiness Scale
Fp	-	Frontal parietal
HENS	-	Hospital Enterprise Network and Systems
Hz	-	Hertz
ICSD	-	International Classification of Sleep Disorder
IoT	-	Internet of Things
ISI	-	Insomnia Severity Index
ITU	-	International Telecommunication Union
NREM	-	Non-Rapid Eye Movement
OFFSA	-	Offline-First Sleep Assessment
OPMA	-	On-Premises Monitoring and Alert
OSA	-	Obstructive Sleep Apnea
PSG	-	Polysomnography
PSQI	-	Pittsburgh Sleep Quality Index
REM	-	Rapid Eye Movement
SWA	-	Slow Wave Activity
TMSFI	-	Telemonitoring System for Insomnia

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LIST OF PUBLICATIONS

Journal with Impact Factor

Azman, N., Ghani, M. K. A., Wicaksono, S., R., Kurniawan, B., and Repi, V. V. R. 2020. Insomnia analysis based on internet of things using electrocardiography and electromyography. *Telecommunication, Computing, Electronics and Control*, 18. Pp. 1406-1415. (Scopus indexed, Q3, IF=1.8 (2020))

Azman, N., Ghani, M. K. A., Wicaksono, S., R., and Salahuddin, L. 2019. The development of IoT tele-insomnia framework to monitor sleep disorder. *International Journal of Advanced Trends in Computer Science and Engineering*, 8. Pp. 2832-2839. (Scopus indexed, Q4, IF=1.2 (2019))

Conference Proceedings

Azman, N., Ghani, M. K. A., Satria, M. H., and Mukaram, M. Z, 2018. October. Development of embedded system for centralized insomnia system. In *2018 5th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)* (pp. 451-455). IEEE.

CHAPTER 1

INTRODUCTION

1.1 Background

Insomnia is the inability of an individual to have a proper quality of sleep, which will create a relaxed state of the body and a fresh state of the mind. Insomnia is defined as the quality of sleep and the situation which determines our feelings towards the outcome of the quality of sleep attained; however, it is not measured by the duration of our sleep and the condition of whether we could get sleepy easily (Ohayon, 2002). Although insomnia is categorised as a symptom or a type of health disorder, it is often considered as a comorbid condition that is related to one specific medical state or other mental disorders (Akyar & Akdemir, 2014). Based on the research conducted by Murali et al., (2003) insomnia can create a risk of hypertension, which is around 350 per cent bigger than the normal people who rarely have this health issue. It is also a factor that causes an individual to have diabetes and expose him or her to suffer from anxiety and depression (Murali et al., 2003).

On the other hand, the research investigated by Prasetyo et al., (2018) shows that the prevalence of insomnia symptoms experienced by governmental officers in Jakarta is around 50%. It consists of 44,2% indicating the mild symptoms of insomnia and 5,8% for the medium level of insomnia. 30% of the factors causing this prevalence in adults involve the difference of working hours, stress on work, work burden, the total office hours in a week, and mental or emotional disturbance. The prevalence of insomnia can be in different levels or forms since it depends on the companies or offices, which have different jobs,

work stress, work environment, or work pattern, showing the correlation between complications at work and the quality of sleep.

Sleep disturbance is related to the mental, physical, and social health (Roth et al., 2011), the declining standard of life quality (Kyle et al., 2010), the rising number of accidents and absence at work (Shahly et al., 2012), even the most extreme is a fatal injury at work (Laugsand et al., 2013) and suicides, which is caused by a long and heavy state of depression (Ribeiro et al., 2012). All of these are stimulated by chronic insomnia, which has occurred for a long time. The effects of insomnia on an economic situation are also moderately critical, including the loss of productivity and the expensive medical costs for health treatment. Based on the study conducted in Canada, it has spent a total cost of 191.2 million Canadian dollars for the immediate treatment related to the health consultations for insomnia; the transport cost for the consultations, which is around 36.6 million Canadian dollars; prescribed medicines involving 16.5 million Canadian dollars; free products helping the insomnia treatment, which are around 1.8 million Canadian dollars; and also alcohol used for sleep stimulation, which needs 339.8 million Canadian dollars. There is also another cost, which is not immediately connected to the treatment of insomnia, and it needs 970.6 million Canadian dollars in a year. Finally, the financial loss created by the low productivity because of insomnia has been estimated at 6.6 million Canadian dollars (Daley et al., 2009; Garland et al., 2018).

However, insomnia cases are often neglected. Only a few people seek consultation or remedy for their problems related to insomnia from the health service providers, although the effects of sleep disturbance caused by insomnia have significant impacts on themselves, other people, and the public.

The diagnosis of insomnia is usually based on the subjective and objective information collected from a patient who complains of insomnia (L. Zhang & Zhao, 2007).

The objective insomnia measurement is conducted by using Polysomnography (PSG) as a tool for recording the sleeping process of a patient in a whole night. Polysomnography (PSG) is recognised as a qualified tool with a reputation as the golden standard, and it has a function to identify a great number of sleep disturbances (Thorpy, 2012). Nevertheless, the data analysis and evaluation of PSG take time, need high cost, involve a complicated process of using the tool and evaluating the data. These complications do not prevail only to the experts, who treat insomnia, but also to the patients. The limited facilities of testing the sleep disturbances caused by insomnia, which are available only in big cities, give impacts on the patients of insomnia in these cities, who gave an additional time burden to the patients who live far away from the cities and do not have access to the facilities. The need of having a trip to the cities which have the facilities will take time and produce an additional cost besides the cost of taking the sleep examination by using the facilities.

1.2 Research Motivation

It is essential to have a new approach in conducting an early detection and analysis on the sleep disturbances caused by insomnia, which are effective for saving the budget and time for the patients. The detection and analysis must be conducted remotely between the patients and the medical team so that the patients do not need to spend their time travelling to the cities where the facilities for testing the insomnia case are available. The new approach will increase the availability of the services for sleep examination in the cities which do not have the facilities, and it can reduce the costs and time spent by the patients. This innovation will minimise the expenses and time to have a trip from the cities where the patients are originally from to the cities which have hospitals or clinics supported with the qualified facilities for testing sleep disturbances.

1.3 Research Problem

Insomnia is the problem of general health in medicine and psychiatry. Sleep disturbances are often underestimated and not considered serious. The situations create mental and physical disturbances for those who suffer from insomnia. One research conducted by Kidwai and Syed has shown the surprising increase of insomnia patients in the developing countries in which 16.6 per cent of respondents are from Ghana, Tanzania, India, Bangladesh, Vietnam, and Indonesia, and they suffer from insomnia as well as other sleep disturbances (Kidwai & Ahmed, 2013).

The prevalence of those who suffer chronic insomnia has risen significantly in urban cities. The urban lifestyle and the social-economic demands are some causes of the rise of patients with chronic insomnia (Liu and Liu, 2005; Xiang et al., 2008; Asghari et al., 2012; Zailinawati et al., 2012). The prevalence creates an indirect impact on the social and economic factors in a country, where around 60 per cent of the people in the developing countries live in the cities.

As an individual, the patients with chronic insomnia can influence their quality of life and the comorbid situations of their health (Daley et al., 2009; Kyle et al., 2010). The research conducted by Vgontzas et.al., (2009) has shown that the patients with chronic insomnia will have an increased risk for hypertension, reaching around 350 per cent higher than those who have normal sleep hours (Vgontzas et al., 2009). Insomnia is also a factor that can trigger the risks of diabetes, anxiety, depression of a patient. All of these, then, will influence their performance rhythm at work and their social life.

Polysomnography is a tool with a gold standard to measure sleep disturbances collected from the data involving the factors which cause the disturbances. However, because of the routine of clinical evaluation, polysomnography is not practical and limited to be used in certain places (Kushida et al., 2005). There is another device commonly used