The use of wearable devices in the workplace- A Systematic Literature Review

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Abstract. The aim of this Systematic Literature Review is to provide a heuristic overview on the recent trends of wearable technology and to assess their potential in workplaces. The search procedure resulted a total of 34 studies. In more details, 29 different types of wearable devices were obtained from the studies. Categorization revealed that obtained wearable devices were used for monitoring: 18 types (e.g. for mental stress, progress, etc.), augmenting: 3 types (e.g. for data, images), assisting: 3 types (e.g. to uplift their work), delivering: 2 types (e.g. for vital information contents) and tracking: 8 types (e.g. sedentary behaviour). To sum up, though wearable technology has already gained momentum for personal use to monitor daily activities, our studies shows that it also has potential to increase work efficiency among employees, improve worker's physical well-being and reduce work related injuries. Further work in terms of privacy, usability, security, policies, cost of devices and its integration to the existing system is required in order to increase the adoption rate of wearable devices in workplaces.

Keywords: Wearable Technologies; Wearable Devices; Workplace; Benefits; Occupational Health; Wearable Robotics; Systematic Literature Review

1 Introduction

Evolution of technologies such as computers, smart phones, has dramatically reshaped the workplace over the past couple of decades. This evolution has also occurred at the workplace as most job descriptions have changed from manual labor to predominantly physically inactive duties (e.g., desk jobs, automated assembly lines, etc.) [18]. At the same time, employees are working longer hours *to meet the requirements of the job, anticipation/expectation of higher earnings in the future, increasing volumes of work, job insecurity, employee's preference, occupational commitment and career enhancement* [12] [16]. This can potentially have enormous effect on physical well-being of employee, likelihood of occupational injuries and illness [6]. According to Baka, "Occupational accidents still occur, despite technical developments in the occupational safety field at large" [1]. A potential injury occurs at the industrial environment due to complex, hazardous conditions [1][13][8] and fatigue. Studies conducted by various researchers and managers have generally recognized that health and well-being can potentially affect both workers and organizations in negative ways [5]. Kritzler states that, "companies suffer significant financial losses every day due to illness and poor health of their employees [13][1]. Therefore, there

is need for improvement in health and safety, which can bring benefits to both company as well as employees.

Companies have started incorporating ICT based approaches in to their health and safety promotion programme designed to improve worker's health and safety, and reduce health care costs [4] [14][20]. Currently there is a great inclination to modify well-being concept and health care by changing the technology in "wearable"[7]. These technologies have gained increasing traction in recent years for personal use to track data about everyday lives and physical well-being. Following the same tendency, we assume that this technology could be immediately useful in workplace.

Wearable technology also called wearable devices or gadgets, as an autonomous, powerful system that are worn in human body or attached to clothing worn by human to perform the specific task or function [9]. Wearable Technology offers new opportunities to monitor human activity continuously with the miniature wearable sensors embedded [3] in garments. A key benefit of wearable technology is to improve in productivity, efficiency, connectivity, health and wellness [19].

The question then becomes how wearables could strike out potential benefits in the work place. In order to unfold potential benefits, firstly, it is necessary to discover what types of wearable devices can be used in workplaces, how these wearables devices can be integrated in to day to day business activities *(i.e.to increase safety, level of physical activity, reduce their stress and increase productivity and efficiency)* based on previous researches, we performed the systematic literature review guided by Kitchenham and Charters [10].

This study provides an overview on the research trends and patterns and the usage pattern of wearable technologies for workplaces from 2000 to 2016. The paper is organized as follows: section 2: *how research process been conducted*; Section 3: *findings of this study and presents an interpretation of our results*; Section 4: *discussions*; and Section 5: *concludes the paper.*

2 Research Methods and Questions

– **Research Process:** A systematic literature review has been adopted and applied, in line with Kitchenham and Charters [10] guidelines, terminology and Petersen et al. [17]. According to Kitchenham and Charters a systematic literature review can be defined *"as means of identifying, analyzing and interpreting all available data relevant to the particular research question or topic area in an unbiased way"*[10]. The overview of the adopted process consists of following phases:

- *Definition of the research question, based on the objective of the research.*
- *Conduct a search of articles for primary studies by using search strings on scientific libraries, databases. Tools like NAILS bibliometric software* [11] *can also be utilized for this purpose.*
- *Screening the initial set of articles, by applying inclusion and exclusion criteria to determine whether each potential study should be included.*
- *Classification of articles based on the keywords from the abstracts of selected articles.*
- *Classification and categorization of articles based on the final set of keywords.*

Petersen et al. [17] recommends researchers doing systematic reviews to investigate and make use of alternative ways of presenting and visualizing their results. Finally, the results were

consolidated from the relevant articles and presented in the form of graphs, tables, or other form of graphical representations.

- **Research Questions:** The overall objective of the systematic literature review is to identify the types of wearable technologies that can be utilized in workplaces and whether these technologies can be beneficial for different business stakeholders (corporate, internal and external). Hence, given that we specified three research questions (RQs) together with a rationale for each one to obtain more inclusive overview on the topic:

- **RQ1:** ***What types of wearable technology are mentioned in literature in between 2000-2016 that can be used in the workplace? To what extent wearable technology can be utilized in workplaces?***
  Rationale: *identifies the range of wearable technologies under study in recent time and possible areas of future development.*
- **RQ2:** ***What benefit does wearable technology give for the company and employees?***
  Rationale: *indicates the extent to which whether wearable technology can be beneficial for companies and employees, which provides information about the likelihood of development in wearable technology.*
- **RQ3:** ***What challenges still remain and need further investigation by research communities?***
  Rationale: *provides information that can be serve as a basis for ascertaining future research direction.*

- **Search Design Process:** We started the primary studies search by using the search strings on online search databases. The following electronic databases were searched: ACM digital library, IEEE Xplore, Science direct[1] and web of knowledge. We have chosen the stated databases because they are identified as relevant to information technology field. From the identified papers, we also manually browsed the citations [21]. The search strategy used to formulate the search terms (ST) was composed of following 4 phases as described in (Fig. 1):

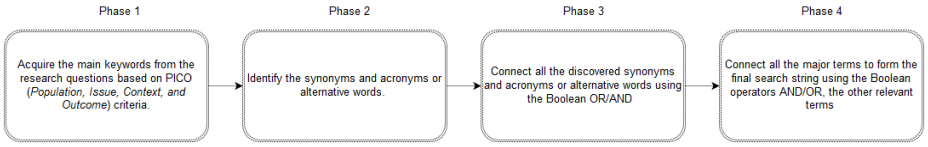

Fig. 1. Search string formulation process

In **phase 1**, we formulated the search terms based on research question using PICO criteria[2]. In our studies, we have discarded comparison and outcome as we not comparing any devices or measuring anything in our study. In **phase 2**, we identified possible synonyms and acronyms or alternative words for search terms (i.e. ("wearable"; "wearable device"; "wearable computing"; "wearable technology"), ("workplace"; "work"), ("benefit"; "advantage"). In **phase 3**, we merged all the identified synonyms and acronyms or alternative words of search

[1] www.sciencedirect.com

[2] PICO Criteria: http://learntech.physiol.ox.ac.uk/cochrane_tutorial/cochlibd0e84.php

terms by using the Boolean "OR". Finally, in **Phase 4**, we connected all the major terms to form the final search string using the Boolean operators AND, the relevant articles whose publication date was since 2000 onwards, as *(""wearable*" or "wearable device*" or "wearable computing" or "wearable technolog*")* **AND** *(""workplace*" or "work")* AND *("benefit*" or "advantage*") AND ("publication year >2000").*

By utilizing the above predefined digital databases sources with their search utility, and formulated final search string, we conducted the initial search process in March 2016 and the final set of search in 30/06/2016. Additionally, search was also conducted using the Google scholar in order to find any relevant articles as well as to cross check the final sets of retrieved papers to determine the relevance of each paper.

- **Article selection Process:** The aim of the article selection process was to find those articles that are relevant to the objective of this systematic literature review based on inclusion and exclusion criteria. Thus we applied the following set of inclusion and exclusion criteria to select the relevant publications to answer our research questions. The inclusion criteria (IC) formulated and applied are: **IC1:** *Publication date between 1/1/2000-30/06/2016;* **IC2:** *Includes answers for at least one of the research questions;* **IC3:** *Includes if study conducted related about workplace, using wearable technology;* **IC4:** *If several papers reported by same author, only the most recent one is included;* **IC5:** *Only papers written in English.* The exclusion criteria (EC) formulated and applied are: **EC1:** *Paper that limited discussion about wearables;* **EC2:** *If it doesn't cover the enhancement of workplace productivity;* **EC3:** *Technical documentation or reports that are available in the form of abstracts and secondary literature reviews.*

  In the beginning, automated search led to 359 articles from *IEEE Xplore (166), ACM digital Library (7), Science direct (181)* and *web of knowledge (5*). After refining the results based on the above predefined exclusion and inclusion criteria, such as keywords, abstract, full text, titles were in English and duplicate articles, final 34 studies were selected for data extraction and analysis.
- **Data Extraction:** Template was used to register the relevant information from the final set of reviewed articles. The data extraction (DE) process included following input from each selected primary resources: Metadata: *Study ID (S1, S2...,), Author(s), Year of Publication, Paper title, Name of the Conference or Journal in which study has been presented, Keywords, Topic, Database in which study was found.* Because we are interested to find and analyze the data with respect the RQ, we extracted the data as: *Types of wearables (if Applicable);* RQ2, *Utilizations (if Applicable):* RQ2; *Wearing position (if Applicable):* RQ2; *Benefits:* RQ3.

  Overall, 12 data fields were created to extract data from selected articles. (See APPENDIX: A)[3]

3 Results

We gathered and analyzed the data from 34 articles (see APPENDIX: B)[4] from 2000 to 2016. Based upon the analyzed data, results related to the systematic literature review are presented in

[3] APPENDIX A: http://step.lut.fi/data/uwd/Appendix_A.pdf

[4] APPENDIX B: http://step.lut.fi/data/uwd/Appendix_B.pdf

this section. Even though, search was limited, between 2000 to 2016, relevant articles only started to appear around 2009. This seems to indicate that recently there has been growing interest among researchers in this topic. The following section highlights the important results:

RQ 1: What types of wearable technology are mentioned in literature in between 2000-2016 that can be used in the workplace? To what extent wearable technology can be utilized in workplaces?

The main objective of this research question is to identify the range of wearable technologies that has been extensively mentioned in recent years. The first part of research question concerned what types of wearables has been addressed in workplaces. The search led to the identification of 29 types of wearables from relevant papers. These identified devices are listed in APPENDIX: C[5]. Literature review revealed that there are five ways how wearable technologies has been utilized in workplaces which are explained below:

1. **Monitoring *[Study ID S3, S5, S6, S7, S8, S10, S11, S12, S15, S19, S20, S27, S28, S29, S33, S34]:*** It allows employees to collect ongoing health information via series of activities using the devices. We have found out most of the selected studies used wearable devices in their workplace to monitor work related stress [S12], [S15], [S19], [S27], [S28], individual and social behaviour [S10] [S12], progress [S3].
2. **Assisting *[Study ID S4, S14]*:** It allows employers to provide external tools which are worn in body to control their posture, or lift heavy items. We also discovered that some of the studies used hydraulic and electric powered exo-skeletons to assist the workers in order to uplift the heavy load [S4] as well as to control posture of the workers [S14]. Exo-Skeleton is defined by Looze et al. [15] as *a wearable, external mechnical structure that enhances the power of a person.*
3. **Augmenting *[Study ID S1, S9, S12, S13, S21]*:** It allows employers to deliver digital information, such as: images, text, videos on devices such as HMD's, glasses while wearer views the real world. According to Gartner Research[6], wearable augmented device is going to be an important tool for companies to enhance key business activities such as business process, training, etc. Experiments conducted by [S12] [S13] found out that by augmenting, employers can improve employee performance by initiating training tools. We have discovered that employers can use the AR devices for employer's productivities [S12], [S13], remote guidance [S26], health and safety improvement [S1], industrial design [S13], [S21], and maintainance work [S1].
4. **Tracking *[Study ID S6, S7, S10, S16, S17, S18, S24, S25, S30, S31, S32, S34]*:** Through this usage, employers will be able to track worker's position, movement through the use of devices deployed on the body (e.g. arm movement, distance travelled). For example: Study conducted by [S24] [S25] used devices [T15] to track employee's sedentary behavior.
5. **Delivering *[Study ID S3, S9, S21]*:** It allows employers to deliver the content and to the users via device allowing them to read, listen or watch context provided by third parties. Based on Chen et al. [S3], wearable can provide just-in-time information which are currently not possible with paper on-site construction processes.

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5 APPENDIX C: http://step.lut.fi/data/uwd/Appendix_C.pdf

6 http://www.gartner.com/newsroom/id/2649315

By implying the utilization of wearables in workplaces, we clustered the obtained wearables type under categories *(C1): Monitoring; (C2): Assisting (C3): Augmenting; (C4): Tracking; and (C5): Delivering.* From the categorization, we found that various types of wearables devices were used for monitoring: 18 types, augmenting: 3 types, assisting: 3 types, delivering: 2 types and tracking: 8 types. Based on the findings, we have created the usage of wearable framework in workplaces (See APPENDIX: D)[7]. We have also discovered that, three devices were utilized for multiple purpose.

Studies shows that simpler devices such as digital pedometer [T15], smartwatch [T1] can help employer to get minimal data from tracking the worker's activities whereas advanced technologies such as EEG devices [T8], EMG sensor nodes [T9] can help employer to gather complex data in order to create and deploy effective physical well-being strategy. We have also found out that same wearable devices such as HMD's [T21], EEG devices [T8], Digital pedometer [T15] can be utilized for multiple purposes while other can fit for only specific purpose.

RQ2: What benefit does wearable technology give for the company and employees?

As described in previous section, wearable technologies can be utilized for multiple purpose. In this section, we analysis how wearable technologies can be beneficial and provide long lasting effects in work place. From the primary studies we found out that, the benefits of wearable technologies in the workplace is highest when they are introduced to:

- **Monitoring physcological and physiological factors of the employees:** Many employers are unaware of their employee's physio-social and physical-stress levels and the effects it at the workplace. One of the quotes by Dr. Deming [2] *"if you can't measure it, you can't manage it"* fully implies in workplace. Unless employer monitors working environment it is difficult for them to know if their employees are getting worse or better with regards to performance level.

  Wearable technology can be valuable tool in workplace to monitor and refine the wellness initiatives of the employees. From the study, we found out that many devices have been used for tracking physio-social stress (stress about the job) and physical stress (working hard with the equipment's) or tracking the physical activities of the worker. One of the benefit of wearable technology is active monitoring by taking the advantage of the data delivered by wearable devices. With those data, employers could take active steps towards assisting their employees either via discussion about the issues or creating physical activities. This will help employees to relieve stress, tension and live physically and mentally fit.
- **Enhance operational efficiency:** Wearable devices such as HMD's (such as smart glass, Microsoft HoloLens) can be utilized for remote guidance. By using HMD user's hands are totally free and the user's vision is unobstructed. The person who is giving the guidance can see exactly the same things as the one who is being guided, through the camera in the mounted device. This means that one giving guidance can see the real world and the created 3D images from the camera. 3D images can be created into real world surfaces for the guided person to see and they can be interacted with different types of touch gestures [S26]. With the help of AR, communication becomes more accurate and easier to understand which also effects on work performance.

[7] Appendix D: http://step.lut.fi/data/uwd/Appendix_D.pdf

- **Workplace safety and security:** Employee's safety is always important in any workplace, especially in hazardous jobs where employee is for example working in a mine, operating heavy machinery, construction site or in a job where employee is dealing with high voltages. From the literature review, we found out that safety and security can be improved with the help of accurate monitoring using wearables.

  Yang et al. [S33] found in their study that, it is possible to detect the dangerous working spots (places where happens the most near-miss falls) with the collected data from wearable devices. Another study conducted by Sole et al. [S30] found out that RFID tags can be used to improve workplace safety and to limit false alarms. Baka et al. [S2] explained in their paper that, wearable could be used to detect and warn the user when step voltage hazard exists. According to them, two sensors (transducers) can be attached to user's feet so that they are in contact with skin. These sensors can detect the user's body current and work as monitoring system, when the dangerous potential differences are starting to occur. When the user is approaching dangerous zone, the device warns the user. This clearly shows that wearable use in workplace has clear benefits to improve workplace safety for employees.
- **Industrial designing:** Wearables integrated AR technology can be used for example designing construction plans [S13], blueprints [S13], building information modeling [S13] and aircraft cabins [S21]. As a result, task can be done virtually without any extra cost such as overhead, travelling, onsite meeting. Study conducted by [S21] discovered that AR can be used in manufacturing purposes for maintenance and measuring the wires for vehicles before installations which will lead to save time and cost.
- **Improve worker's health:** Working posture are always problematic for all kind of jobs. However, computer related jobs, construction works, mining can be taken as the examples due to lots of physical strain it can cause to the backside of body. When the working posture is bad for years, it is highly likely to cause low back disorders, more so in more physically demanding workplaces as mentioned. Eurofound also observed that level to exposure to some risks such as (particularly 'tiring and painful positions' and 'repetitive hand or arm movements') has shown an upward trend [16]. Luo et al. [S14] conducted study on this issue where he designed WSAD (Wearable Stooping-Assist Device) for stooped work. As the name imply, this device reduces the strain from a stooping posture and so it prevents the risks having a low back disorder. Chu et al. [S4] also experimented wearable robots (exo-skeleton) to improve worker's health in shipbuilding work. [S4] used exoskeletons to decrease the muscle strain on lower limb muscles of workers and to support vertical load. This type of support helps preventing possible musculoskeletal disorders. In this study [S4] used two different prototype exoskeletons, i.e., standard type and gooseneck type. Exoskeleton's mobility and usability was tested for several hours. Though exoskeletons had certain limitations, such as lifting capacity and maximum walking speed, the workers did confirm that the exoskeletons improved work efficiency and seemed to help preventing muscular diseases.

RQ3: What challenges still remain and need further investigation by research communities?

Data analyzed from the studies have shown that, wearable devices can have benefits to the workplace. However, there are still some remaining challenges which needs to be investigated and resolved. During our primary studies, we have identified following open challenges that still needs to be further investigated by research communities:

- **Usability:** It has been established from the research work of Khakurel et al. [9], device characteristics (size, battery life, modalities, etc.) were the most discussed usability issues that have limited the ways in which users can interact with the wearable devices. Hence, in this study, we have also found out that size and battery life [S3], [S20], [S31] are the most important parameters. In order to increase adoption of wearable devices at workplaces and improve the usability of the users, re-searcher should further investigate on how size and energy consumption of the system can be minimized by increasing the memory size [9].
- **Privacy:** One major issue identified in the studies [S11], [S12], [S16], [S34] is the violation of privacy because data generated from wearable devices contains, vital information of employees, such as heart rate, number of steps taken, etc. Researcher's needs to investigate what kind of data employees would like to handover and create further guidelines related to which type of wearables can be applied in workplace and what kind of data can be extracted and analyzed.
- **Adoption:** One of the challenges, we found from the studies is the adoption of wearables [S12], [S20], [S22] by both employees and employers. The adoption of wearables and also the willingness to share the data with employees would require vast amount of awareness. Further research should investigate new incentives, motivation and workplace performance model with the integration of wearables.
- **Cost factors**: Other key challenges for employers is the complexity and cost of integration with existing system. Chen et al. [S3], found out for companies it is necessary that Return of Investments (ROI) exceeds the cost of obtaining information wirelessly. Research communities should investigate the ways to developing and integrating low cost wearable devices to the existing system.
- **Accuracy:** From the studies [S19], [S21], [S28], we have found out that data delivered by wearable devices are not 100% accurate. Also from the studies made by Khakurel et al. [9], one of the usability issues for wearable devices is accuracy. Therefore, there is need for further studies to develop the higher accuracy sensors and algorithms to ensure that quality and accuracy of data remains creditable.
- **Security:** Like all other technologies, wearables are vulnerable to hackers. From the studies, we have found that employers are concern from possible cyberattacks which can lead to breach of security data. Further research on how this possible attacks can be eradicated after implementing devices in workplaces.

4 Discussion

The focus of this section is to discuss the results obtained during the systematic literature review and are based on interpretation and exploration of the retrieved data.

Based on this literature review, we can clearly see that wearable technology is not only popular for entertainment purposes but it is also starting to be a valid solution for workplace needs. Our findings show that the majority of the reviewed papers reported several devices (e.g., smart watch [S11] [S33], digital pedometers [S7] [S22] [S29], electronic shirts [S33] and HMD'S [S3] [S21] that are being used for entertainment or lifestyle purposes, can also be applied for workplace usage.

Carrying and detaching multiple technologies on the body could lead more stress for workers. It is necessary for workplace to investigate and combine multiple technologies to create single service to monitor the employees. For example, use of wristbands which can monitor the activities, to get through doors in work-place or as a timestamp device. This way the wearable device would not feel like a thing that an employee has to wear every day just to be monitored.

In some cases, it was also noted that using wearable devices also increased work performance. This was the case for using exoskeletons and HMD's. Exoskeletons also help preventing muscular diseases by lowering the physical strain on the body. So this type of device has actually two great benefits. The problem with wearable exoskeletons is however the fact that the safety standards for them in workplace usage are still in progress and they are still more in experimentation stage. In the near future however, wearable exoskeletons would be a great asset especially in industrial and construction type of work where there are a lot of heavy lifting.

Having healthy employees are important for the company and being healthy is obviously a desirable thing. As this work indicated, this type of monitoring can be used for finding out the cause for stress and then possibly limiting it by taking necessary actions. Also by monitoring physical changes in body, it may be possible to detect possible illnesses and get proper treatment for them, before they get more serious. By using wearable devices, the safety of workplaces can also be improved as it turned out in the text.

5 Conclusion

The aim of this study was to provide systematic literature review of the current trends of research and future perspectives of wearable technology in workplaces. Following predefined criteria, we identified and analyzed around 34 relevant articles.

Results revealed that there has been many experimentations and implementations for several types of wearable devices in different kind of workplace environments. To achieve research goal, we identified the types of wearables and categorized in terms their mode of use. We also observed that some wearables can be used for multiple purposes while some can be used for specific purpose. Findings revealed that, most of the identified devices are still in prototype stages but have the potential and will be definitely a useful tool in workplaces in the near future.

Most of the benefits of wearable devices in workplace addressed focus on employee's health, workplace safety and improved work performance. However, wearable technology has limitations which need to overcome, with regards to technology, privacy, cost, accuracy, adoption and design.

In conclusion there are a various types of wearables that can be utilized in workplaces for different purposes. Wearable technology in the workplace are relatively new concept to improve health and safety of the workers and have gained significant momentum over the last few years. Although, wearable technologies have been great assets for personnel use, it is still a relatively new area of research for use in the workplace where issues such as usability, privacy, cost factors, data accuracy issues are yet to be resolved.

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