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Smart wearable technologies to promote safety in aging construction labor

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Abstract

Societies across the globe are facing aging populations that present significant challenges in the design and construction of high-rise buildings. In the wake of this demographic change particular attention must be paid to an aging workforce's safety on-site and the impact that smart technologies could have in the prevention of accidents from a worker's lack of functional capacity.

This study aims to develop a questionnaire survey to collect the required data on the monitored activities older construction workers perform, and the implementation of this monitoring for the prevention of accidents on-site. Initially, the smart technology that is crucial to the adoption of such an approach will be introduced. Next the history of wearable technologies, both successfully and unsuccessfully applied to elderly users, will be analyzed. Consequently, and drawing on the primary data gathered via the questionnaire, this study will present relevant information from 15 small and medium-sized construction firms. This study uses statistical methods to represent a basic approach towards identifying significant factors from the questionnaire results. Finally, it will be shown that this data will prove useful to researchers, contractors and construction companies within the scope of effectively integrating gerontechnology in the construction stage of projects.

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1. Introduction

Technological development is rapidly increasing around the world, and smart technologies are an increasingly important field of research as changing demographics make an impact on the demand of new markets which could benefit older users. The construction industry is one of the most prolific industries in the Korean economy but, in the period from 2008 to 2017, the construction sector was second amongst all production sectors in terms of the frequency of injured workers and represented some 28% of the overall workplace mortality rate [10]. The construction industry has thus become one of the most dangerous sectors within which to work in Korea.

In the face of such statistics it is now widely agreed that wearable devices (WD) have the potential to transform safety in the construction industry. The research problem thus becomes how WD are perceived by construction companies and individual users, and how those perceptions influence WD adoption and applications in a working environment.

2. Literature review

For the purpose of this research, the term “gerontechnology” refers to the use of technology concerned with aging; it can be defined as the development and adaptation of technology toward the goals and ambitions of aging and aged people [3]. Today much information about gerontechnology is being published while, at the same time and almost unceasingly, different policies, technologies, and innovations are reviewed by professionals concerned with age-associated changes [11]. Several studies [12], [13], [14], [15] have highlighted different methods for the implementation and adoption of technologies for improving daily activities and the quality of life of older people.

Technologies like smart wearable devices are defined as any technology that is worn by a user in the form of an accessory with integrated electronic and computing technologies, and that captures or reports some type of data. The wearable device can collect and store data from the user’s physical activity, movement, heart rate, and even audio data, any or all of which can later be analyzed. In Korea, one in every five people own a wearable device, with 13.3% using a smartwatch, and 1.2% using smart glasses [9]. Though the smartwatch segment continues to be the leader in wearable devices, Gartner predicts strong growth in the ear-worn segment [4]. In 2014, the global market for wearables was worth \$9.2B [5], with a forecast to be more than \$84 billion in 2022 [4]. This could mean easier access to participants as technology demands will increase and a major portion of the population will likely already be using a wearable device.

Changing technologies have shifted the application of digital technologies towards the well-being of aging adults by providing activity tracking, health coaching, health monitoring, and so forth. [3]. Acceptance of smart wearable devices is affected by a wide range of factors (social influence, perceived usefulness, and attitude towards use, among others) related to both the physical and cognitive changes accompanying the process of aging [6]. Research by MaRS Discovery District, a large-scale innovation center, suggests baby boomers will be the next group of primary adopters of smart wearable technology, denoting the importance of exploring factors surrounding their adoption by this aging segment of the population [5]. Hence, positive attitudes and the acceptance of these devices are vital to their successful incorporation into working environments such as construction sites.

REFLEX by Kinect is a smart wearable device that aims to capture the user's biomechanics to determine when they are moving with an incorrect posture. The novelty of REFLEX is the social encouragement it gives to users by setting personal goals and inspiring friendly competition in order to reduce unsafe postures and encourage better work habits. In addition, the collected data provides the user with real-time feedback to reduce the likelihood of injuries [6].

Myant SKIIN is a clothing-based wearable where sensors and actuators are directly knitted into the clothing making it feel like any other everyday undergarment. This technology is capable of capturing health data such as heart rate, temperature, activity, hydration and measuring body fat [7]. The data is then transmitted to the SKIIN Platform where the health information can be consulted and assessed, allowing older workers to remain independent without facing a plethora of repeat visits to the hospital or health clinic.

Both of the smart wearable devices above offers the benefits of being incorporated into daily activities without being disruptive to the working cycle of the older-individual. As previously stated, a key factor in incorporating this technology into the working environment is the positive attitude and acceptance by the user. Currently, there is not an explicit theory to explain and predict the adoption rate, acceptance, or the decision to use a WD, but the Unified Theory of Acceptance and Use of Technology (UTAUT) can provide insight as to some relevant factors [4]. The UTAUT has been used to study caregivers use of e-health interventions [3], adult use of virtual reality in a clinical setting [3], and occupational therapists intended use of virtual gaming with older adult clients [3].

Previous reports indicate that occupational accidents are detrimental to employee health on construction sites; this study analyses the use of wearable devices as an intervention method to monitor and generate improvements in older worker construction safety, as well as decreasing the risk of accidents. Technology product managers must identify opportunities to compete effectively for share and value in smartwatches, head-mounted displays for VR and AR, ear-

worn devices, wristbands, and smart garments [4]. The existing literature does not yet address these factors with regards to WD adoption in the construction sector; this is the research gap this study aims to fill.

3. Theory

In order to address wearable technology solutions for an aging labor force in Korea, and recognizing the importance of this factor in this implementation, it was necessary to analyze the data stored in both the Korean Statistic Information Service and the Construction Safety Management Information System. Within these two governmental databases the records of the last ten years related to the status of accidents in the Korean construction site were explored in order to identify the main labor problems, specifically for the accident type, the accident cause, and any relation to the aging workforce. The importance of this data is in detecting the main problems that might have been prevented or even solved with a technological intervention.

3.1. Types of accidents at the construction site and causes

As shown in Fig. 1 [2], the highest risk of accident is related to a collapse of materials, accounting for 32% of all occurrences and representing 43% of overall fatalities and 42% of all injuries, between 2008 and 2018. Second behind collapse, falls also prove significantly dangerous for construction workers (16% of occurrences, 14% of fatalities, 12% of injuries). Combined, these two dangers represent 48% of occurrences and could point to the sorts of problems and hazards the construction industry and its aging labor force might address through the adoption of smart WDs.

Fig. 1. Type of accidents at the construction site

The Korean Statistic Information Service registered a total of 518 accidents on construction sites of which the most common cause was improper construction operations. This cause was responsible for an overwhelming total of 118 deaths representing 36% of the workplace fatalities in the construction industry and 25% of all construction workers injured. Overall, with a total of 286 accidents we can confidently state that 55% of accidents are due to improper construction operations, operational error, and inappropriate worker behavior.

3.2. Aging society and the South Korean construction industry

The number of older adults (+60 years) in the Korean construction labor force has risen almost threefold between 2009 and 2017 (Fig. 2) from approximately 93,000 to 276,000, with the elderly share of the Korean population increasing from 5 percent to 14 percent during that same period. The increasing number of older adults we can expect in the

future creates an impetus for making significant improvements to the risk of accidents, construction related injuries and deaths, and the overall older worker welfare in the Korean construction industry.

Fig 2. Employed persons by age group (in thousand persons) [1]

3.3. Device and equipment selection

A review of the different wearable devices was conducted to produce Table 1, and each device's unique features outlined. The selection criteria for the devices included functionalities and feature sets that may be useful for monitoring older adult health factors and exploring how suitable their advantages are to prevent construction accidents.

Table 1. Device and equipment fitting application

Device	Properties	Advantage to diminish types of accidents in elder workers	Limitations	Fitting application
Smartwatch	User-friendly interface with both touch and voice commands	Physiological wellness, navigation, fitness/activity tracking, heart rate monitoring	Battery limitations and outdoor/indoor inadequacy	x
Head-mounted display	Controlled by touching the screen, head movement, voice command, and hand movements.	Task coordination, visualization of scenery and information, AR/VR, easy communication	Motion sickness, battery life and price	Collapse and fall warnings
Smart clothing	No visual interaction with user via display or screen, data is obtained by body sensors and actuators	Heart rate, daily activities, temperature, and body position tracking	Ensuring the electronics still work after repeated washing	Alerting mechanism fit for fire alarm, fall and collapse alerts
Ear-worn	User-friendly interface with both touch and voice commands	Ambient noise reduction, hands-free calling, multi-device connections, and activity tracking	Battery life and power	Vital signs monitor fit for fall and collapse alerts
Wristband	User-friendly interface, accurate data is obtained through algorithms and sensors	Can detect oncoming dangers and immediately send this data to an outside manager or technical specialist for assistance.	Battery life and power	Fall and collapse alerts

4. Analysis of figures

We have analyzed a variety of wearable devices that are currently on the market for use by older people; identified a theoretical framework to support the acceptance and use of technology by older users; assessed labor challenges in the Korean construction industry; considered the steady increase of older labor in this industry, and; produced a comparison table to serve as a guide by which to incorporate selected wearable technologies according to the needs of the specific construction company.

Previously, a gap in the literature was identified and, hence, the assertion of 11 fundamental factors that influence older user adoption of technologies in the workplace served as the basis for the development of a questionnaire for 15 small

and medium-sized construction firms. This research survey expands on findings from a prior study conducted by the researchers Debnath A., et. al. [8], wherein a survey was used to detect the dominant factors on the acceptability of wearable devices in Bangladesh.

The research emphasized in the study data and enumerated in the integration of wearable devices factors [6] suggests adopting safety technology can curb the increasing number of workplace injuries and fatalities in the construction industry. Thus, individuals were asked to rate the importance of these factors with a response range from 1-4, where 1 represented *no importance* at all, and 4 represented *most important*. According to the responses offered, the various factors were prioritized, and technological solutions recommended.

4.1. Survey

The qualitative survey research covers the perceptions of 15 professionals from within the industry and was composed of two sections: a background section and a main section. The background section was designed to discover more about the construction company participant's knowledge; hence, the participants were questioned with regards to: 1) the type of company they worked for, 2) their primary role within the company, 3) their years of experience, 4) their level of understanding of safety on a construction site, 5) their level of understanding of wearable devices as a means of deploying smart technology in the construction industry. The second and main section emphasizes the factors affecting the adoption of wearable devices in Korean construction companies [Fig. 3], so the participants answered, according to their professional perspective, as to which factors had a major impact in the implementation of wearable technology for their aging labor force activity monitoring as deployed in their own construction company.

4.2. Data analysis and results

The observed results [Fig. 3] indicate that the primary factor identified by participants impacting acceptance was *perceived risk*, followed by the *perceived cost*, *perceived trust*, and *lack of knowledge*. As shown in Table 2, the best means to target the perception of risk, cost, and trust in wearable devices is by endorsing assertive measures to enhance the acceptance and implementation of this technology. Specifically, this can be achieved by providing information about where the construction industry is heading and presenting the potential increase of profit the companies could expect by adopting such devices for their aging workforce. In contrast to existing research [8], quantitative analysis demonstrates that the *perceived ease of use* and *social influence* were not significantly associated with acceptance of smart wearable devices among the sample.

Fig. 3. Data analysis of acceptance factors

As a result, theoretical considerations of prioritized factors for the use of wearable technology must be taken into account when seeking their adoption by companies. This data will prove useful to construction companies by providing a scope of the ways by which to implement the technology and the solutions available for adoption in the construction sector.

Table 2. Data analysis and technology correlation

Factors	Factor solution
Perceived risk	Reducing complexity of usage, cost-effective acknowledgment
Perceived cost	Present the increase of profit in long term, technology education
Perceived trust	Achieved by eliminating consumers' perceptions of risk
Lack of knowledge	Assertive promotional measures
Perceived usefulness	Comparing effectiveness and profits with WD usage
Facilitating conditions	Provide a support system to facilitate the understanding of the devices

5. Conclusion

The present research serves as a platform on which to develop guidelines to properly integrate new wearable technologies into a construction environment where age-associated limitations will become more common as the demographic pyramid continues to invert. Of course, given the small sample, the use of a convenient sampling method, and the large number of dimensions being tested for association and correlation, the research has some limitations. However, this research generated several important elements of background information about the advantages of wearable devices adoption by the elderly in other sectors and provides key factors for this technology adoption in the South Korean construction industry.

Improper operations and improper behavior by workers are two of the main causes of safety issues in the construction industry and both frequently cause labor to experience injury and even death. In the face of this reality, the deployment of wearable devices in the work environment can help monitor work processes, create a healthier and safer workplace, and improve the productivity of personnel. With the continuous advancement and innovation in technology, it can be expected that construction safety issues will, in time, find a broader range of affordable smart wearable technologies available for adoption.

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