Wearable Technologies: How Will We Overcome Barriers to Enhance Worker Performance, Health, And Safety?

Discussion Panel

Christopher R. Reid[1], Mark C. Schall Jr.[2], Ryan Z. Amick[3], Jeffrey M. Schiffman[4], Ming-Lun Lu[5], Marty Smets[6], Haifa R. Moses[7], Ryan Porto[8]

[1]The Boeing Company, [2]Auburn University, [3]Wichita State University, [4]Liberty Mutual Research Institute for Safety, [5]NIOSH, [6]Ford Motor Company, [7]NASA, [8]General Motors

Wearable technologies are changing the way that people interact with the world. Personal physical activity monitors are becoming ubiquitous in our society and are helping to advance user health and performance, yet, many workplaces have not broadly adopted the technologies beyond either low fidelity/complexity pedometer-based applications or, inversely, high fidelity/complexity lab-based evaluations. Considering adoption of wearable technologies in the workplace, some technology-related concerns include; (1) types of data needed to be captured (motion, muscle, temperature, etc.), (2) constraints of sensor design, such as human-sensor system integration (embedded in clothing versus strapped to person), ruggedness, form factor, or weight, and (3) types of data interpretation and feedback applications that exist to translate data into useful information (communication, trend mapping, situational awareness).

From the research design perspective, there is difficulty in conducting studies capable of demonstrating a safety or productivity that supports employing wearable technology in the workplace. Difficulties include poor access to workplaces and varied worker populations to conduct research, lack of funding, and the need for extended time periods to demonstrate utility (often longer than the lifecycle of the technology in question). Considering the industry perspective, barriers to adopting wearable technologies include lack of convincing data, cost, and anticipation of reduced productivity, poor usability, and/or information overload. Additionally, employee privacy concerns and public policy implications may provide challenges. Another potential barrier may be that some practitioners, however, believe that innovative technologies may be adopted without rigorous testing. This may have short term success to garner interest but may create a barrier to adoption in the long term if the devices are found to have no near or mid-term efficacy.

The overarching goal of the session will be to improve understanding of different perspectives as it relates to the use, barriers, and adoption of wearable technologies and generate discussion for overcoming such barriers to improve the process of research to practice to research (RtPtR). The panelists are from a variety of industry sectors and academia. The session will begin with a 5-minute introductory statement from each panelist; therefore, most of the session will be a discussion between panelists and audience.

Moderators: Christopher R. Reid, chair & Mark C. Schall, co-chair

PERSPECTIVES FROM AEROSPACE MANUFACTURING

Christopher R. Reid, PhD
Environment, Health & Safety,
The Boeing Company,
Charleston, SC

Wearable sensor technologies are changing the way that people interact with the world. While personal physical activity monitors are becoming ubiquitous in our society and are helping to advance user health and performance, many workplaces have not broadly adopted the technologies in an industrial based human safety or worker performance application. Human Factors and ergonomics is the science concerned with understanding human capabilities and limitations for a given task and making sure that the task demand levels are within those human limitations. In crew deck applications for aircraft, sensory systems are utilized by designers to enable successful completion of flight for pilots. Similar objectives can be applied when designing for assembly and maintenance environments. Good designs should allow mechanics to complete tasks safely and efficiently without having to choose between their own safety and that of the hardware.

Mechanics who build the products are subject to common ergonomic risk factors such as manual material handling, repetitive movements, overexertion, confined space hazards, and performance based errors. Poor productivity and quality re-work in addition to human injury are a result of sub-optimal human-centered product design. These negative outcomes ultimately add to the cost of manufacturing for the company. In turn, it is due to these complex and unique manufacturing design issues that wearable technology might prove itself as a potential benefit for company cost savings.

Agnostic platforms are being assessed that utilize integrated motion and physiology sensors along with human modeling and virtual reality technologies that proactively aims to reduce ergonomic risks and improve human efficiency through more human centered design. The intended goal is to develop sensor protocols that accurately models and monitors human capabilities in both digital design and real-world environments. Enabling these capabilities in product development and current manufacturing provides objective and repeatable methods to analyze ergonomics with real humans in the loop (e.g., design engineers, mechanics, safety, etc.) interfacing with digital design definition or the actual manufacturing environment. In the end, use of these 3D environmental renderings can serve as visual training tools to assist designers and mechanics in learning how to minimize bodily strain, maximize hardware protection, and optimize process efficiency.

PERSPECTIVES FROM ACADEMIA: AUBURN UNIVERSITY

Mark C. Schall, Jr., PhD, AEP
Industrial and Systems Engineering,
Auburn, AL

Technology is continually evolving. “Smart” garments, augmented and/or virtual reality headsets, powered exoskeletons, and high performance mobile computing devices are just some of the many recent wearable technology developments that are breaking into mainstream cultural awareness. The potential applications for such tools in our lives are virtually endless. However, like most devices that have preceded the current wave of technological advancement, designing such technology for seamless integration into the home or workplace can be a challenge.

Wearable inertial measurement unit systems (IMUs) are becoming particularly attractive to ergonomists and safety professionals for their ability to measure kinematics pertinent to human motion. Raw sensor data from IMUs attached to adjacent body segments can be converted to joint angles using an array of sensor fusion algorithms of varying complexity and then summarized using common metrics to describe risk for musculoskeletal disorders. Deciding on which sensor system and algorithm to employ, however, is typically context dependent. Additional research is needed to arrive at a common protocol for best practices. Research on approaches for displaying and operationalizing such data is also needed to promote broader adoption among industry professionals. Advancements into these areas made at Auburn University will be discussed.

PERSPECTIVES FROM ACADEMIA: WICHITA STATE UNIVERSITY

Ryan Z. Amick, PhD
Human Performance Dept.,
Wichita, KS

The field of wearable technology has seen rapid growth over the past number of years. Primarily driven by advances in consumer electronics technology, there seems to be an endless number of options for monitoring physical activity, sleep, and recording various other health metrics. As manufacturers have worked to develop new products, they’ve also improved monitoring capabilities, signal analysis capabilities, and form factor of these devices. Untimely, this has resulted in improved data quality available to the consumer and researcher alike. Looking toward the applications of wearable technology within the field of Occupational Ergonomics, the primary emphasis tends to focus on employee monitoring for the purpose of improving risk analysis techniques. And while there is a need for this work, the potential for wearable technology goes far beyond the realm of monitoring, it can also be used to augment the user’s movement and physiology.

Electroactive polymers (EAPs) are polymer materials that demonstrate a significant change in size and/or shape when an electrical stimulus is either applied or removed. Dielectric (DE) EAP artificial muscle is a soft actuator which has a built in compliant sensing and actuation capability. They are comprised of a polymer film that is located between two compliant electrodes. When a voltage difference is applied, the DE artificial muscle compresses in thickness and increases in area. To date, DE and other EAPs have primarily been used in the field of robotics where mechanical systems are designed to mimic simple biologic structures and their movements. However, as the field continues to progress, EAPs may have significant application in the development of wearable human assist devices. Clothing and other personal protective equipment with embedded soft actuator artificial muscle may be able to improve worker performance as well as reduce injury risk. Additionally, this technology can be used to manipulate various physiological parameters, further improving worker performance and reducing injury risk, especially in extreme environments. Current efforts in the development of wearable DE EAP garments at Wichita State University will be discussed.

PERSPECTIVES FROM THE LIBERTY MUTUAL RESEARCH INSTITUTE FOR SAFETY

Jeffrey M. Schiffman, PhD
Center for Physical Ergonomics,
Liberty Mutual Research Institute for Safety,
Hopkinton, MA

Wearable sensor technology is a rapidly growing field, with many start-up companies producing new products that span multiple applications. The technology components are also rapidly advancing with regards to sensor types, sensor fusion, and form factor. Areas of application include sports, healthcare, auto, and the workplace. The Research Institute is interested in the feasibility of wearable sensor technology to aid in workplace safety and risk assessment associated with overexertion, falls, struck-by injuries and related disability. However, given the uncertainties around the capabilities and limitations of current technology in addressing problematic use cases, we are proceeding with caution. We are especially interested in understanding advances in algorithm development that will make best use of this technology. In considering if wearable technology is ready for deployment in the field to help with risk assessment, we strive to understand the limitations of the devices as they relate to generalizability, the potential to introduce new safety risks, the ability to demonstrate efficacy, and the ability to inform on predictions. Ultimately, one of our goals is to inform on research gaps and generate knowledge needed so that the wearable technology may be deployed to enhance and easily assess work performance risk on the job. As such, one important consideration is that wearable technology includes sensors that are easily and unobtrusively worn on one's body to monitor safety, and measures exposure reliably, accurately and precisely in naturalistic settings. We currently have a variety of projects on wearable technology that relate to (a) overexertion, (b) distracted driving, (c) slips trips, and falls, and (d) better understanding barriers to wearable technology acceptance in the workplace. There is little question that wearable technologies will mature and offer important new possibilities but, to date, the evidence regarding the safety value and intervention potential of existing technologies is lacking. Therefore, we remain interested in learning about new developments and technologies, while also generating new knowledge and scientific understanding of the mechanisms that underlie wearable technology use to assess safety and risk.

PERSPECTIVES FROM THE MUSCULOSKELETAL HEALTH PROGRAM, NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)

Ming-Lun Lu, PhD, CPE
Organizational Science and Human Factors Branch
Division of Applied Research and Technology,
Cincinnati, OH

Ergonomic checklists or photo/video risk analyses are commonly used by practitioners for estimating postural risks for MSDs. These risk assessment methods, however, are subjective, resource intensive; and cannot effectively quantify a variety of postures used by the worker during an 8-hour workday (Callaghan at al., 2001; Lu et al., 2015). The advancement of wearable inertial measurement units (IMUs) presents a great potential for researchers and practitioners to address the limitations of current risk assessment tools for MSDs associated with manual work in the workplace.

Wearable sensor-based posture risk assessments for MSDs appear to be desirable by practitioners. In 2009, the NIOSH Direct Reading and Sensor Technology workshop, joined by many researchers and industry stakeholders, identified several desirable features of a practical ergonomic risk assessment method. The features in the desired order included no interference with job, no subjective risk measures and immediacy of risk exposure results (NIOSH, 2009). Because wearable sensor-based risk assessment methods meet the above desirable features, they are anticipated to have a large impact on the industry by providing tools to easily estimate postural risks for MSDs and help in identifying intervention opportunities.

Computer algorithms have been developed by many companies for processing data from IMUs to characterize body position or motion for fitness purposes. The application of the IMUs in measuring work-related postural risks for MSDs is lacking. NIOSH has an on-going project to develop computer algorithms for automatically measuring several postural risks for low back disorders associated with two handed manual lifting tasks. The accuracy and practicality of the multi-sensor wearable system are being evaluated at NIOSH and will be discussed to provide insights into the application of the system in the workplace.

PERSPECTIVES FROM AUTOMOTIVE MANUFACTURING

Marty Smets, MSc
Ergonomics Lab, Advanced Planning & Feasibility,
Ford Motor Company,
Dearborn, MI

With the increased sophistication and miniaturization of sensors, industry professionals now have a wide range of solutions available to them. Many of these solutions are now 'wearable' enabling both the measurement and delivery of real time information to the user. Improvements in signal processing, sensor fidelity, and software processing have made many of these complex technologies accessible to a larger audience. This enables practitioners to leverage tools that were previously out of reach to those without specific subject matter expertise in the area. With respect to ergonomics, this enables the transition from simple low resolution risk assessment tools to more accurate but equally more complex methods.

Ford Motor Co. has been using optical motion capture systems to drive our digital human models and risk assessments during virtual assembly for over a decade. These processes can provide valuable insight to ergonomic engineers as to how our *industrial athletes* approach assembly tasks, which often drives design direction. However, these classical methods can be time consuming and difficult to support at the speed of production. As a result, it has been necessary to use these tools only on particularly concerning work tasks. Although not new, IMU based tracking systems have become measurably more accurate in recent years due to improvements in hardware and software development. Their portability, relatively simple setup, low cost (of certain systems), and their usefulness outside lab environments provides a compelling reason for ergonomists to consider adding them to their toolkits. Although compelling, these systems also have their limitations.

Another wearable technology that is slowly gaining interest in the manufacturing community is smart eyewear. These tools can augment reality with timely, contextual information presented to the user in their visual field. This information can be used to ensure work instructions are followed, parts are correctly selected, or many other customizable options. Several proofs of concept are currently under investigation and the practicality of their integration will be discussed with respect to ergonomics.

PERSPECTIVES FROM THE WEARABLE ELECTRONICS AND APPLICATIONS RESEARCH (WEAR) LAB, NASA JOHNSON SPACE CENTER

Haifa R. Moses, MS
Habitability and Human Factors Branch,
Houston, TX

As NASA moves beyond exploring low earth orbit and into deep space exploration, increased communication delays between astronauts and earth drive a need for crew to become more autonomous (earth-independent). Currently crew on board the International Space Station (ISS) have limited insight into specific vehicle system performance because of the dependency on monitoring and real-time communication with Mission Control. Wearable technology provides a method to bridge the gap between the human (astronaut) and the system (spacecraft) by providing mutual monitoring between the two. For example, vehicle or environmental information can be delivered to astronauts through on–body devices and in return wearables provide data to the spacecraft regarding crew health, location, etc.

The Wearable Electronics and Applications Research (WEAR) Lab at the NASA Johnson Space Center utilizes a collaborative approach between engineering and human factors to investigate the use of wearables for spaceflight. Zero and partial gravity environments present unique challenges to wearables that require collaborative, user-centered, and iterative approaches to the problems. Examples of the WEAR Lab's recent wearable projects for spaceflight will be discussed.

PERSPECTIVES FROM THE GENERAL MOTORS GLOBAL ERGONOMICS PROCESS

Ryan Porto, MHK
General Motors,
Warren, MI

At GM, Ergonomics is considered a key enabler to all successful program launches by all levels of leadership. Ergonomics is an accepted core requirement to designing and building vehicles around the world. Our primary focus is to design out systemic product and manufacturing issues and prevent future ergonomics issues before the product goes into production. This is accomplished by the use of Digital Human Models (DHM) and virtual assessments which are part of our Product Lifecycle Management system (PLM).

Due to our ongoing research and collaborations in the academic field, we have improved the realism of the human models and postures when analyzing reach, access, clearance, and the operator's line of sight.

Although significant advancements have been made in predicting operator postures to determine strength capabilities for a given population, there is still a lack of realism for complex postures and the time to complete virtual assessments is still an issue for the Ergonomist. In order to complete virtual ergonomic assessments in a timely manner while keeping up with the rapid changes of the product design, the wearable sensor technology is appealing during the virtual build and prototype phase in the vehicle development.

Initial evaluations within the automotive industry have shown that the wearable suits/sensors have been able to deliver more accurate and faster results for creating a full simulation and for posture analysis. This has been especially prominent in walking, the ingress/egress of the vehicle and sitting postures. However, there have been several limitations when streaming the manikin's properties into the PLM software that is used by the OEM. For example, accurately scaling the motion capture's manikin to the DHM. There seems to be a lack of integration between the specific sensor technology and the DHM that is being used. If these issues can be resolved, the technology would enhance the virtual ergonomics process by way of posture libraries, pre-defined simulations, in plant evaluations and virtual operator training.

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