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The applicability of existing acceptance models for enterprise organizational technology acceptance of wearables

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ABSTRACT

Technology adoption models have historically focused on individual decision–making. However, many times technology is chosen by an organization, and must be adopted by its employees. Wearable technology has the potential to improve a variety of safety and performance outcomes in manufacturing settings, but acceptance by both organizations and individuals is varied. Fourteen focus group interviews were conducted to explore the topic of wearable technology acceptance in manufacturing. The most prevalent acceptance factor from existing models was attitude, with comments generally demonstrated an overall sense of uncertainty and hesitation about how the devices and subsequent data would be used. Several factors, such as comfort, safety, convenience, cost, and culture, were discovered in the focus group results but are not represented in current acceptance models. There is a need to modify existing models or develop new models to better understand wearable technology acceptance.

Relevance to industry: Introducing new technology into an industry setting presents many challenges. Understanding existing barriers can help practitioners explore ways to improve implementation and adoption within a manufacturing organization.

1. Introduction

In 2005, Knight and Baber (2005) noted the growing importance of wearable technology when they developed and published their Comfort Rating Scale (CRS) to assess human perceived comfort of wearables across six dimensions: Emotion, Attachment, Harm, Perceived change, Movement and Anxiety. While the product focus of their wearable research was larger in form factor (e.g., helmets, gloves, backpacks) than the more compact, less invasive wearables to follow (e.g., smartwatches, rings, and glasses), their interest in both function and adoption was well-timed. The following year, Boff would publish his human factors and ergonomics prediction of a "Generation 3" neural fit through a symbiotic coupling of the human and technology (Boff, 2006) that would blur the lines of where the human ends and the tool begins (i.e., wearables) (Burch, 2019). Knight and Baber's simplistic yet preferred definition of wearables (Knight and Baber, 2005) from Gemperle et al. identified the "use of the human body as a support for some product" and "includes the notion of the device being wearable while the body is in motion" (Gemperle et al., 1998). Despite the age of this definition (1998), it aligns with Boff's Generation 3 vision for the future of technology interactions (Boff, 2006) while still accurately describing the popular wearable product market that would be in widespread use over two decades later and estimated at 15 billion U.S. dollars (Luczak et al., 2020).

A 2017 review of the state of wearable technology invention disclosures demonstrates the breadth of wearable form factors and how

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successful inventors have been, since the days of Knight and Baber, combining electronic components, such as sensors, into a multitude of clothing types and wearable products (Dehghani and Dangelico, 2017). The ability to take common clothing components and insert data-capturing solutions into garments and other equipment enables various physiological and kinematic parameter assessments (Luczak et al. 2018). While athletic programs have primarily used wearable solutions to monitor health and safety practices to make individual (Saucier et al., 2021) and multiple season-long observations (Shelly et al., 2020) about performance improvements and injury mitigation, mainstream adoption and continued use can still be an issue.

Within industry, a primary driver for wearable implementation has been the assessment and improvement of ergonomics. Wearables have been used to assess and improve a variety of ergonomics focuses, including posture (Stefana et al., 2021; Ferrone et al., 2021; Oyekan et al., 2021), fatigue assessment (Patel et al., 2022), hazard identification (Patel et al., 2022), and performance optimization (McDevitt et al., 2022). Inertial sensing is often used (Lim and D'Souza, 2020), with the use of inertial measurement units (IMUs) working as effectively as traditional motion capture systems (Humadi et al., 2021). Regarding acceptance of wearables for ergonomic assessment, studies have shown the importance of device design (Laun et al., 2022) and comfort (Gaddis et al., 2022) in wearable effectiveness.

Knight and Baber's CRS (Knight and Baber, 2005) is relevant today as wearable adoption can still be problematic even in highly saturated markets like athletics for reasons beyond essential technology function such as trust, comfort, compliance, and general concern over the use of the data captured (Luczak et al., 2020; Luczak et al. 2018). As other sectors such as industry (Smith et al. Smith; Svertoka et al., 2020; Maltseva, 2020), healthcare (Li et al., 2020), and military (Shi et al., 2019) seek to expand their use of wearables into work performing and work performance spaces, wearable implementation will be at risk of adoption issues based on reasons similar to those found in the human performance domain as well as undocumented concerns.

2. Background

Considering technology adoption from the organization level is vastly different from adoption at the user level, the current level of innovation at an organization may help explain why an organization may or may not adopt new technology for their workforce (Damanpour and Daniel Wischnevsky, 2006; Magsamen-Conrad and Dillon, 2020). Additionally, the level of involvement of the workforce in technology decisions and implementation is critical to widespread adoption (Masood and Egger, 2020). Furthermore, safety climate and performance expectancy, among other factors, impact employee willingness to use an organization's wearable technology (Jacobs et al., 2019). Finally, the external environment and competitors' actions often drive the adoption of technology at the organizational level (Ghobakhloo and Ching, 2019).

2.1. Acceptance models

Technology adoption models have historically focused on individual decision–making. The three primary adoption models are the Technology Acceptance Model (TAM) (Davis, 1985; Davis et al., 1989; Davis, 1989a), the Theory of Planned Behavior (TPB) (Ajzen, 1991a), and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003a). All three models explore the constructs of both use intention and behavior as indictors of technology acceptance.

TAM was developed in 1989 in an effort to explain what factors lead to technology acceptance, with actual usage of a technology being the indicator of acceptance. TPB, developed in 1991, was developed to explain human behavior from social psychology, though it has since been applied frequently to technology adoption and acceptance. Developed in 2003, UTAUT looks at use behavior as the indicator of technology acceptance. While the models were (Venkatesh et al., 2003a; Legris et al., 2003) since been supported by numerous empirical studies in application areas such as driver assistance systems (Rahman et al., 2017a; Isa et al., 2015; Buckley et al., 2018; Sagnier et al., 2020; Manis, Choi), and occupational personal protective equipment (Wong et al., 2021; Man et al., 2021).

The Technology Acceptance Model, TAM, includes three components of behavioral intention towards a new technology: attitude toward behavior, perceived usefulness, and perceived ease of use (Fig. 1). TPB, the Theory of Planned Behavior, also includes attitude toward behavior and the subjective norm and perceived behavioral control (Fig. 2). UTAUT, the Unified Theory of Acceptance and Use of Technology, includes four components: performance expectancy, effort expectancy, social influence, and facilitating conditions (Fig. 3). Each model is predicated on the notion that behavioral intention leads to actual system (technology) use. Some of these models and their encompassing factors may be particularly important to situations in which the organization chooses a technology for employees to use. For example, the voluntariness of use in UTAUT (Fig. 3) is expected to influence employees' acceptance, whereas employees who are mandated to use certain wearables may have differing levels of acceptance than those who can use the wearable voluntarily.

2.2. Acceptance factors

Researchers, technology developers, and safety professionals identify wearable technology as an effective workplace intervention for improving worker health and safety. For example, select technologies monitor worker postures, detect proximity to hazards, and assess worker fatigue (Maltseva, 2020). However, the use of such technology for safety and health is sporadic and varies greatly by industry. Researchers have identified several barriers to the adoption of wearable technology within the health and safety domain. Barriers to the human side of the equation include privacy and confidentiality, lack of incentives for use, and limited employee compliance (Schall et al., 2018; Nnaji et al., 2020a). From the technology side, identified barriers include difficulty integrating the sensors and devices with current technology systems, the complexity of data interpretation, and poor design of the wearable device (Luczak et al., 2020; Luczak et al. 2018; Reid et al., 2017). Some researchers note that worker acceptance of the devices may be even lower than acceptance or adoption by management (Gianatti, 2020; Nnaji et al., 2020b).

Research has often included both individual and organizational factors when identifying factors that may be of particular importance to organization-wide adoption. For example, in a recent model of handheld technology acceptance, researchers identify three organizational factors that influence acceptance: organizational readiness, technical readiness, and environmental readiness (Hafeez-Baig et al., 2018a). Other studies have identified systems-level factors, including organizational factors such as size, decentralization, and strategic focus, along with environmental factors such as competitor pressure and uncertainty (Patterson et al., 2003a).

Refer to Table 1 for the acceptance factors included in the primary acceptance models. These factors serve as the basis of most acceptance modeling research, including studies that expand into organizational-

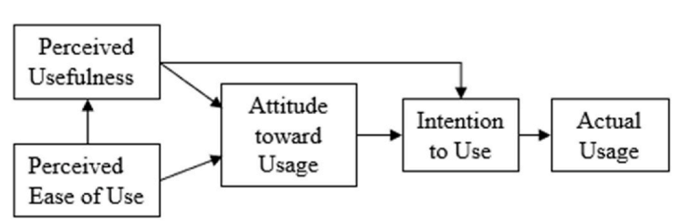

Fig. 1. The technology acceptance model (TAM) (Davis, 1989b).

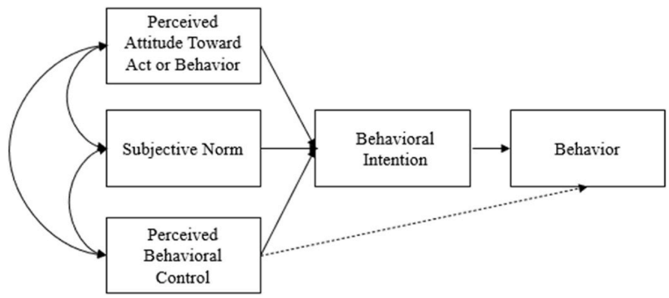

Fig. 2. The theory of planned behavior (TPB) (Ajzen, 1991b).

level decision making and adoption factors (Hafeez-Baig et al., 2018b; Patterson et al., 2003b).

2.3. Organizational models

While the widely adopted TAM, TBP, and UTAUT models guide researchers to understand and explore technology adoption behavior, they are not applicable to situations where the "user is not the chooser" (Ahmad et al., 2012). That is, these models are only applicable when the user of the technology can choose the technology themselves. However, when a different decision-maker is in control of the technology decision, the models no longer apply. Many workplace situations follow this "user is not the chooser" standard, wherein a manager or other person in authority selects a technology to be used by the workforce. The individual worker using the technology is not always involved in the decisions regarding technology adoption. While some authors have explored the notion of technology adoption at the organizational level, empirical evidence of the applicability of these models is not apparent. One such model, Diffusion of Innovations (DOI), was suggested by Rogers (1995). In this model, Rogers posits that the level of innovation in a firm results from three factors: leader characteristics, organizational structure, and external characteristics. A second model, the Technology, Organization, and Environment (TOE) framework developed by Tornatzky and Fleischer (1990), includes technology, organization, and the external task environment. However, both models are theoretical and do not present actionable guidance for influencing technology adoption. Additionally, these models are created within IT systems and have not been expanded to physical technologies such as wearable sensors.

Researchers have explored innovation diffusion to determine why some organizations appear more effective than others at embracing new technologies. Multiple studies have pointed to the critical nature of both stakeholder input (Ahmad et al., 2012), as well as organizational culture (Chan and Ngai, 2007) and external pressures (Tseng, 2017) on technology adoption at the organizational level. However, a comprehensive model of such adoption does not exist.

3. Methods

3.1. Participants

To obtain a comprehensive understanding of wearable acceptance in the workplace, the research team identified four populations of participants: (a) employers (including occupational safety professionals), (b) technology providers, (c) workers, both incumbent and in training, and (d) state agency workforce administrators and workforce strategists.

Project researchers employed a grassroots approach to encourage participation among the target populations. Participating businesses and technology providers were selected based on existing relationships with members of the research team and solicited for participation through email, phone calls, or face-to-face interactions. Everyone contacted was provided with a summary of the goals of the project, information to be collected, and how their participation would help achieve those project goals. Upon confirmation of participation, the research team worked with the participant(s) to schedule a convenient date and time to conduct an interview or a focus group. A total of 14 focus groups were conducted. The focus groups attended by the four populations of interest separately, with a total of seven employer focus groups, four technology providers focus groups, two worker focus groups, and one workforce strategist focus group. No individual personal information was collected from focus group participants. The size of focus groups ranged from six to fifteen, with the majority of focus groups having less than ten participants.

3.2. Instrument

Open-ended questions were developed for each of the target participant groups. Each questionnaire was designed with a specific focus area, a key research question, and an overarching goal to assist the moderator in facilitating the discussions. The number of participant questions ranged from three to four and focused on identifying participants' understanding of wearables in the workforce, their familiarity with wearables technology, and the benefits and detriments of implementing wearables in their current occupation. Participant responses were recorded in one of two ways. First, the research team used the voice recording software installed on a laptop computer for face-to-face focus groups and interviews. Second, for interviews and focus groups conducted remotely, recordings were obtained via the video conferencing technology contained in WebEx or Microsoft Teams.

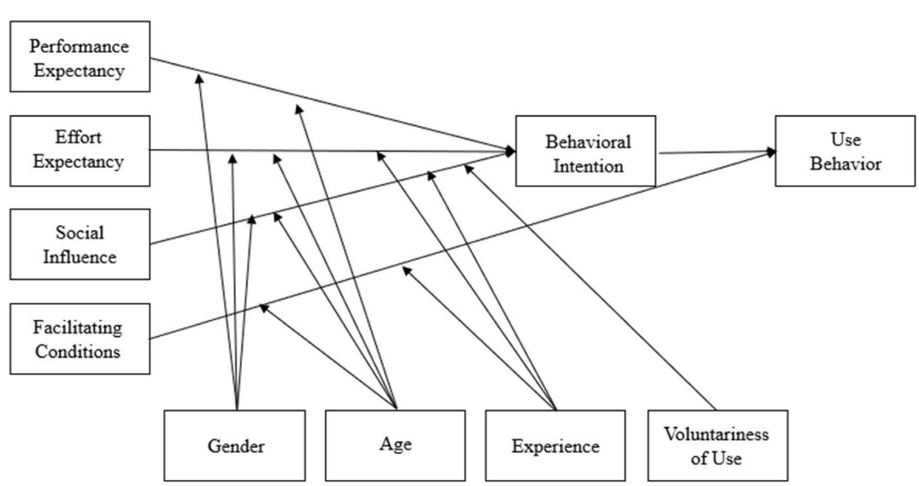

Fig. 3. The unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003b).

Table 1
Summary of acceptance factors in TAM, TPB, UTAUT (from (Rahman et al., 2017b)).

Theory	Factors	Definitions
Technology Acceptance Model (TAM)	Attitude	"An individual's positive or negative feelings (evaluative effect) about performing the target behavior" (Fishbein and Ajzen, 1975a) (p. 216).
	Perceived Usefulness	"The degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989b) (p. 985).
	Perceived Ease of Use	"The degree to which a person believes that using a particular system would be free of effort" (Davis, 1989b) (p. 985).
Theory of Planned Behavior (TPB)	Attitude	"An individual's positive or negative feelings (evaluative effect) about performing the target behavior" (Fishbein and Ajzen, 1975b) (p. 216).
	Subjective Norm	"The person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein and Ajzen, 1975b) (p. 302).
	Perceived Behavioral Control	"The perceived ease or difficulty of performing the behavior" (Ajzen, 1991b) (p. 188).
Unified Theory of Acceptance and Use of Technology (UTAUT)	Performance Expectancy	"The degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al., 2003b) (p. 447).
	Effort Expectancy	"The degree of ease associated with the use of the system" (Venkatesh et al., 2003b) (p. 450).
	Social Influence	"The degree to which an individual perceives that important others believe he or she should use the new system (Venkatesh et al., 2003b) (p. 451).
	Facilitating Conditions	"The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system" (Venkatesh et al., 2003b) (p. 453).

3.3. Procedure

Due to the involvement of human subjects, a summary of planned project activities, all research questions, and a statement of informed consent were submitted to Mississippi State University's Institutional Review Board (IRB) for approval prior to the onset of the study.

All interactions, both face-to-face and virtual, were completed in four phases. In phase one, the research team introduced themselves and provided the participants in attendance with an overview of the study, and asked them if they had any questions prior to recording the session. In phase two, the moderator started the recording and read the informed consent for participation in the study. In phase three, the researchers delivered the questions. Finally, in phase four, recordings were stopped, and participants were thanked for their time and provided with the contact information of the research team members.

3.4. Analysis

Recordings were then uploaded to Filelocker and shared with other members of the research team for analysis. Focus groups were recorded and transcribed through Otter.ai™. A researcher then edited raw transcriptions to match the recorded audio accurately. The researcher performing the edits listened to the recording while reading along with the generated script and then removed any inaccuracies from the AI-powered assistant and produced a final version of the transcript used for analysis.

Once edited, each transcript was uploaded into MaxQDA™ for coding. A total of 33 codes were applied, including codes related to TAM, TPB, and UTAUT. An initial set of codes was developed by the research team based on the acceptance models, whereas other codes were added based on emergent themes from the transcripts. Sections of each transcript were coded if they had pertinent information for each selected code. The presence of exact terminology was not necessary for a code to be applied. Additionally, if a sentence or paragraph had content that applied to more than one code, multiple codes were applied. The initial code assignments were done by one researcher, who did the initial coding for all transcripts. Fully coded transcripts were reviewed by a second researcher confirm that codes applied were relevant to each section. The frequency of each code used was then analyzed in MaxQDA™.

4. Results

Across the 14 focus group sessions, a total of 145 excerpts were coded as relating to one or more of the factors in the three primary acceptance models: TAM, TBP, and UTAUT. Of the transcript excerpts relating to the model factors, "Attitude" was the most relevant factor. "Perceived Behavioral Control" and "Performance Expectancy" had very low relevance based on the number of times focus groups mentioned the factor. Across models, the factors within TAM were discussed the most ($n = 71$ excerpts), followed by TBP ($n = 62$ excerpts) and UTAUT ($n = 44$ excerpts). The number of excerpts coded by model factor is in Table 2, and the number of focus groups that included excerpts related to that factor (of 14).

The appearance of factors in focus groups varied based on the focus group participant type. The most often discussed model factor across participant types varied. Table 3 displays the average number of excerpts from each transcript, further divided by participant type. The average is used for comparison due to the unequal number of focus groups for each participant grouping. For employers, the topics of attitude toward behavior and voluntariness of use were the most discussed of all factors. Technology providers showed the same trend. Workers were most likely to discuss those two factors, in addition to perceived usefulness and age. The workforce strategists had a bit of a different trend, with high averages in excerpts related to attitude toward behavior, facilitating conditions, and age. was attitude toward behavior, with employer focus group transcripts containing an average of 1.9 excerpts and worker focus group transcripts containing an average of 6.0 excerpts per session. The worker focus group transcripts had more emphasis on perceived behavioral control compared to other participant types (see Table 4).

Table 2
Frequency of acceptance model factors in focus group transcripts.

Model Factor	Frequency	# Focus Groups
Attitude Toward Behavior	37	11
Perceived Usefulness	23	12
Subjective Norm	21	10
Social Influence	21	10
Facilitating Conditions	15	8
Perceived Ease of Use	11	6
Effort Expectancy	8	4
Performance Expectancy	5	4
Perceived Behavioral Control	4	2
Voluntariness of Use	*28*	*10*
Experience	*5*	*3*
Gender	*0*	*0*
Age	*18*	*9*

Table 3
Average number of excerpts per focus group by model factor and participant type.

Model Factor	Total	Employer (n = 7)	Technology Provider (n = 4)	Workers (n = 2)	Workforce Strategists (n = 1)
Attitude Toward Behavior	2.6	1.9	2.0	6.0	4.0
Perceived Usefulness	1.6	1.6	0.8	4.0	1.0
Subjective Norm	1.5	1.6	1.0	3.0	0.0
Social Influence	1.5	1.6	1.0	3.0	0.0
Facilitating Conditions	1.1	1.1	1.0	0.5	2.0
Perceived Ease of Use	0.8	1.3	0.0	1.0	0.0
Effort Expectancy	0.6	0.7	0.0	1.0	1.0
Performance Expectancy	0.4	0.4	0.3	0.5	0.0
Perceived Behavioral Control	0.3	0.0	0.3	1.5	0.0
Voluntariness of Use	*2.0*	*2.0*	*1.5*	*3.5*	*1.0*
Experience	*0.4*	*0.6*	*0.0*	*0.5*	*0.0*
Gender	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Age	*1.3*	*1.3*	*0.0*	*3.0*	*3.0*

4.1. TAM factors

Attitude. Attitude was the most often coded factor from the behavior models. Participants reported a mixture of positive and negative attitudes about wearable devices. For example, one participant stated, “you have the frontline employee who is going to independently have their own concerns, fears, and excitement about wearing wearable technology.” There was a general attitude of excitement over trying something new, but also many negative attitudes regarding tracking employee behavior and privacy. For example, comments included “monitoring is a problem for some people that can’t stand having anything on them,” “I mean it depends on the job, but I wouldn’t like to be tracked every second,” and “I see a risk of losing employees or, or not attracting employees or something of that nature because of privacy.” The attitude comments generally demonstrated an overall sense of uncertainty and hesitation about how the devices and subsequent data would be used.

Perceived Usefulness. Participants overall found a high level of perceived usefulness for wearable devices. “But, you know, most importantly, it would drive continuous improvement, whether it’s safety, quality, lean, whatever that is. So that’s a great point. It may be that objective devices, they all work on the right things.” Perceived usefulness was exceptionally high when the discussion centered around using the wearable devices for safety monitoring and injury prevention. One participant summarized it as “technology has made it [the manufacturing facility] more safe.” Another participant related the usefulness of the wearable technology to being superior to former methods of assessing safety and productivity: “So we have technology now that can move us past these, these archaic paper forms and things like that time studies and stuff like that, that we’ve been doing for years.”

Perceived Ease of Use. When first introduced, participants often discussed ease of use as a barrier to using devices or technology. For example, one participant stated, “But they’re annoying to set up. Like it’s very weird on how you set it up.” The difficulty in setting up and learning new technology, in general, was viewed as a negative influence on overall adoption. “I think people have a lot less patience with newer technology, in general. So, on the implement implementation side, if it if you run into a road bump, those can be a little bit more derailing than they would if it was something not as technologically new to the person.”

Table 4
Quotes regarding additional factors from focus group transcripts.

Factor	Frequency	# Focus Groups	Participant Quotes
Culture	25	8	“That is area specific, process area and leadership specific. So, some areas depending on how the leaders in the area, feel about the technology buy-in quicker and utilize it more fuller than other areas where people are more suspect of the technology and believe it to be more of a headache than it’s worth. So, the leadership in the area is a large part of the success or not of using that technology in the area.”
Cost	20	9	“You know, you’re investing in this wearable technology? What does it bring to the table? You know, how can it improve productivity or reduce waste in order to pay for itself? So, you know, from my standpoint, it’s, you know, it’s ROI.” “But not unless you’ve put someone in place or a system in place or done work and effort and resources on the front end to be able to accommodate the new data, to get the benefit out of it that you know, you can get, there’s gonna be some amount of budgetary concerns or resource concerns to be able to handle the new technology and new data coming.”
Convenience	12	8	“And that value could be now let me back up that value could be the efficiency of collecting the data itself.” “When you have humans do that it’s slower, it’s less accurate … So I think the accuracy piece is probably the biggest one.”
Safety	8	5	“Safety is a big concern with those kind of things in an industrial environment, because you don’t want to be wearing watches or necklaces around moving machinery. So that’s got to come off.”
Comfort	6	6	“Yeah not if it’s annoying. It’s just like with anything else, if it causes some kind of hindrance, there’s no reason.” “Comfort is a big thing. For me, I like having things on my wrists, but I also like fidgeting a lot. So, if it has to be specifically placed on one location, that’s not going to work.”

4.2. TPB factors

Attitude. The attitude factor appears in both TAM and TPB. See the results presented in the TAM factors section regarding attitude.

Subjective Norm. Participants talked of the importance of social influence on technology adoption at two primary levels: leadership and coworkers. With support from leadership, particularly supervisors, the devices may be more accepted. One participant stated that this was especially true if supervisors were using the devices to improve safety: “If you present it as a safety measure, and, and looking at healthy work environment, I think you’ll get a lot of support from that.” However, the framing of the messaging from leadership is also essential. An inherent distrust of data usage was again noticeable in responses such as this: “Yeah, they would probably resist the wearable. But you know, and that being said, that’s why I say who’s going to be responsible for the data? You know, how you say that this isn’t for your supervisor yadda yadda, and then all that gets blown out of water. Because inevitably, everybody talks." A few focus groups mentioned the importance of using social influence positively. One participant stated that technology adoption was "usually led by your cultural evangelists. Like there's one guy that's locked in and said, Nope, not for me. And then everybody follows suit. Whereas if the guy would have said, Hey, everybody, I think this is worth trying, you might get more people bought in."

Perceived Behavioral Control. Behavioral control is centered mainly on the perceived learning curve associated with new technology or a new wearable device. Participants talked about what they were "used to" working with and the attempts to transfer what they already knew to the new technology. Participants indicated that they would not have much control if the technology differed from what they used before.

4.3. UTAUT factors

Performance Expectancy. Performance expectancy was mentioned amongst four different focus groups and had a positive association with technology each time. When asked about the use of technology in the workplace, one participant stated that the quicker employees have their "hands on [wearables], the more interest they develop, the more likely they're going to be successful." When discussing potential hiring employees, another participant emphasized the need for experience in technology. They stated, "A lot of our equipment is state of the art," and that employees must "understand how it works … to have the operation running."

Effort expectancy. The consensus was that wearable technology is perceived as challenging to use. One participant stated that there would be "really strong hesitancy" when implementing wearable technology with skilled craftsmen because they are used to using their hands and "didn't want to have to deal with all the computers … and stuff like that." Another participant stated, "technology generates issues as well, especially on the front end, it takes quite a bit of support to get that value out of it. You can't just implement it, and it's all positive."

Social Influence. One participant said, "The leadership in the area is a large part of the success or not of using that technology in the area." Another participant stated, "I have to find the most influential influencing person in that facility, and I have to win them over before I ever even start the project. If you don't, there's no shot … If one person says no, they don't want to do it, I mean, you can create an entire wash of a program … and then they push back at you." Another mentioned, "Because all it takes is one person … once one person says, they're tracking … even though that's not true … that spreads throughout the whole plant and … nobody's gonna want to work."

Facilitating Conditions. Several focus groups talked about the lack of organizational or technical structure when implementing new technology. One participant stated, "Automation is great. But if we have something automated, then the engine changes that no longer accommodate that automation. It's costly to change your automation. So, it's kind of a double-edged sword for us." Another participant said, "it's better data … but not unless you've put someone in place or a system in place or done work and effort and resources on the front end to be able to accommodate the new data, to get the benefit out of it." When asked if workforce strategies have changed to adapt to integrating new technology, one participant answered briefly, "So, I do not. I do not think so."

4.3.1. UTAUT facilitating conditions

As seen in Fig. 3, UTAUT also contains four facilitating conditions: gender, age, experience, and voluntariness of use. Gender was not coded in any of the focus group transcripts. The presence of the other conditions in the transcripts are described below.

Voluntariness Of Use (ten focus groups mentioned, coded 28 times). Many participants brought up hesitancies with implementing new technology due to invasion of workers' privacy. One participant said, "I think our employees will have a sense of distrust about the wearable technologies … Just kind of that Big Brother feeling." Another stated, "There's always some level of distrust. I think you can just overcome it better by having a more complete, diverse team roll it out. That includes more viewpoints than just one." When asked what it would take for them to use a wearable personally, one participant said, "So, like, if it's part of my PPE (Personal Protective Equipment), I'd wear it." Another participant said, "If it helps me do my job, I'm more likely to use it than if it's just being I'm being told that I have to use it."

Experience (four focus groups mentioned, coded six times). When asked about the difficulties of implementing wearables, one participant stated the challenges of convincing workers with no previous experience to use them:

> "One thing I've learned is it's hard to break habits. So, let's say here is a person that's been working on the job for 15 years, they've been doing it their way for 15 years … And they're like 'Well, I've been doing fine 15 years without it.'"

One workforce development instructor talked about the difficulty of implementing new technology with students who have no prior experience with computer work. "… The students that I get come from industry or are contractors, they're used to working with their hands." They go on to say, "if you give them that, like you're talking about what your computer can fix, they're lost. They're used to working with their hands." On the same topic, another workforce development instructor said, "Now what's coming out of high school, they're extremely comfortable with the phone. But they're not very comfortable with a computer. They're not as computer savvy as students were ten years ago."

Age (9 focus groups mentioned, coded 18 times). When it comes to age, most focus groups noted that younger employees would accept new technology more readily than older employees. One participant stated, "… the older generation will be harder to get to, not necessarily hard to get to use it, but just they don't like the change. They want things kept like it is." They continue, "Your younger guys would have it unlocked and able to do things we didn't even know it could do by lunch, you know, so, but the I feel like the older generation would be the harder ones to get on board." A participant that works with an older workforce said, "I think it has to be, it has to stay simple and user friendly for our workforce to adapt." Another participant said, "This is a relatively young workplace. So, I think technology is much more embraced as a, it's almost a novel thing a little bit. Something to try."

4.4. Additional factors identified

While all factors from TAM, TPB, and UTAUT were present in the focus group discussions, many additional items were discussed related to the acceptance of wearable technology in the workplace. The most common additional factors were comfort, safety, convenience, cost, and culture. Excerpts from the focus group transcripts related to these factors are in Table 3.

5. Discussion

The present study explored wearable technology acceptance from the viewpoint of seven distinct workplace populations (i.e., employers, technology providers, workforce strategists, occupational safety professionals, workers, & state agency workforce administrators) across 14 focus group sessions. Analysis of responses yielded 17 distinct factors impacting participants' perceptions of wearable technology acceptance. To contextualize these results, participant responses were further evaluated across three published models of technology acceptance, the TAM, the TPB, and UTAUT. Although approximately 71% of the factors identified fit into at least one of these existing technology acceptance models, the comfort, safety, convenience, cost, and cultural factors were left unexplained.

Evaluating these five unexplained factors through the lens of the theoretical models of organization could provide insight into how existing acceptance models could be modified to address wearable technology acceptance more comprehensively. For example, evaluating the unexplained factors in terms of the TOE framework (Tornatzky and Fleischer, 1990), factors of technology component could be exemplified by the comfort and convenience factors, the organization component by cost and culture, and the task environment by the factor of safety. In relation to the DOI framework (Rogers, 1995), the leader characteristics component of the model is illustrated by the convenience and cost factors, the organizational structure component by the safety and culture component, and the external characteristics component by the factor of comfort.

By obtaining firsthand accounts of wearable acceptance in a manufacturing setting among a diverse group of respondents, the current study supports and extends the current technology acceptance models. Results support the challenge of technology adoption models in selecting a singular framework to evaluate and increase adoption in the workplace. Participant findings highlight the need for an updated comprehensive technology-specific adoption model for occupational settings, in which the end-user is not the decision maker. In addition, the study observed multiple instances of factors contained in each of the three individual models, except for the gender factor in the UTAUT. However, identifying five additional factors not included in any of the current models indicates that more research needs to be conducted to obtain a more comprehensive understanding of wearable technology acceptance either through modification of current models or the postulation of new and more inclusive models.

6. Conclusion

The overarching goal of the current study was to obtain a comprehensive understanding of wearable technology through direct interaction with the individuals in the manufacturing industry most impacted by decisions to adopt wearable technology. To accomplish this goal, the current study combined questions from individual technology acceptance models with the more conceptual, organizational models of technology acceptance. The resulting analysis identified five factors associated with acceptance not accounted for in the existing (individual) technology acceptance models. These findings indicate that both technology acceptance models as well as organizational models need to be considered to understand wearable technology acceptance comprehensively.

Although limited to investigating wearable technology acceptance in a manufacturing setting, the study provides a solid foundation for future investigations into wearable technology acceptance by identifying the gaps in the current individual models and areas in organizational models that could potentially bridge those gaps. Modifying existing models or developing new models based on the current study would be a positive next step to building a complete understanding of wearable technology acceptance. In addition, ongoing studies are being conducted with industry partners in which employees use wearable devices throughout the work shift. Survey and interview data from these field studies will be instrumental in understanding the prevalence of barriers and adoption for wearable technology in practice.

Author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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