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Wearables can help me learn: A survey of user perception of wearable technologies for learning in everyday life

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Abstract

Wearable devices are a popular class of portable ubiquitous technology. These devices are available in a variety of forms, ranging from smart glasses to smart rings. The fact that smart wearable devices are attached to the body makes them particularly suitable to be integrated into people's daily lives. Thus, we propose that wearables can be particularly useful to help people make sense of different kinds of information and situations in the course of their everyday activities, in other words, to help support learning in everyday life. Further, different forms of wearables have different affordances leading to varying perceptions and preferences, depending on the purpose and context of use. While there is research on wearable use in the learning context, it is mostly limited to specific settings and usually only explores wearable use for a specific task. This paper presents an online survey with 70 participants conducted to understand users' preferences and perceptions of how wearables may be used to support learning in their everyday life. Multiple ways of use of wearable for learning were proposed. Asking for information was the most common learning-oriented use. The smartwatch/wristband, followed by the smart glasses, was the most preferred wearable form factor to support learning. Our survey results also showed that the choice of wearable type to use for learning is associated with prior wearable experience and that perceived social influence of wearables decreases significantly with gain in the experience with a fitness tracker. Overall, our study indicates that wearable devices have untapped potential to be used for learning in daily life and different form factors are perceived to afford different functions and used for different purposes.

Keywords Smart wearables · User perception · User attitudes · Learning · Education

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1 Introduction

The popularity of wearable devices has increased immensely in the past decade. Many forms and types of wearable devices are available that provide a variety of functions and come in an affordable price range. With technological advances, the public perception of the smart wearable device has evolved. A wearable device was initially understood as technology worn on the body, mostly to track health and fitness (Rodgers et al., 2014). A more recent definition of a wearable device is "a category of electronic devices that can be worn as accessories, embedded in clothing, implanted in the user's body, or even tattooed on the skin. These devices are hands-free gadgets with practical uses, powered by microprocessors and enhanced with the ability to send and receive data via the internet" (Hayes, 2020). The enhanced capabilities and a multitude of form factors of wearable devices have opened them up to a variety of uses.

While wearable devices are already widely recognized and adopted in healthcare and fitness (Custodio et al., 2012), they are now gaining popularity in education as well. Research has been done on using a wearable to assist learning for specific purposes in specific setups, like using wearables in a lab (Thees et al., 2020), in a classroom (Lee et al., 2016), or during a workshop (Peppler & Glosson, 2013). However, little prior research has explored the use of wearable for learning in everyday life where much fewer constraints exist. In this paper, through an online survey, we explore people's perception of how wearables can be used to support learning in everyday life in terms of general attitudes, scenarios of use, features, and functions. We expect that results from this exploration will help researchers and designers in understanding the value of pursuing research in wearables for learning in everyday life, and the kinds of possibilities that people expect to see.

In the next sections, we first present a review of the current state of wearable devices in terms of features and form factors and the potential of wearables for education. The related work section reviews prior research on technology acceptance of wearables, wearable use in education, and people's perception of wearable use in education. We then present our research question, the survey design, and study procedures, followed by data analysis and results. Finally, we discuss our study results in light of prior findings in the literature and summarize possible future research directions.

2 Background: Wearable devices

Wearables are gradually transforming from providing limited features, such as notification and fitness tracking to providing features, such as inbuilt cameras, speakers, independent GPS, advanced processors, diverse sensors, independent connection to the internet and to other devices, and many more. Recent wearable devices, such as the *Apple Watch Series 5* is pretty much a stand-alone device with features such as making calls without being teetered to a phone, compass, and voice assistant (Apple Inc., 2020). Another example is the *Aina ring*, which allows the control of other electronic devices remotely, and many other functions such as calling a cab, listening to music, talking to google, all without having to use a smartphone (Lazy Design Private Limited, 2018).

Wearable devices are available today in a variety of form-factors, ranging from head-mounted devices to smart footwear. Technology is now frequently incorporated into many of the accessories we wear. Motti and Caine (2014) identified 18 different wearable form factors. Commonly known wearable types include smartwatches and wristbands, smart clothes, smart glasses, smart bracelets, smart necklaces, smart rings, smart shoes, smart gloves, badges, and even implantables. Table 1 shows examples of wearables that are currently commercially available at the point of writing this paper to provide the reader with an overview of the current state of wearables.

Each wearable form factor provides specific kinds of affordances, with affordances being defined as how users perceive a device can be used, and the kinds of actions they see as being possible with it (Norman, 1988). Motti and Caine (2014) list a series of factors that can guide perceived affordances in the holistic human-centered design of wearables: aesthetics, comfort, contextual-awareness, customization, ease-of-use, ergonomics, fashion, intuitiveness, obtrusiveness, overload, privacy, reliability, resistance, responsiveness, satisfaction, simplicity, subtlety, user-friendliness, and wearability.

For wearable devices, affordances can be provided not only by their location on the body and their material property as an accessory (Rapp & Cena, 2015) but also by a variety of user factors, such as users' amount of knowledge about wearables

Table 1 Examples of current commercial wearables

Wearable name	Type	Features	Reference
Apple Watch Series 5	Smartwatch	Cellular calling, compass, voice assistant, activity tracking, sleep tracking, etc.	Apple Inc., 2020
Fitbit Inspire	Smart Wristband	Activity tracking, calorie tracking, sleep tracking, heart rate monitor, etc	Fitbit Inc., 2020
Aina Ring	Smart Ring	Remotely controlling other electronic devices, calling a cab, playing music, voice assistant, etc.	Lazy Design Private Limited, 2018
Ditto	Smart Clip	Notification alerts for call, texts and apps, alarm, tether phone, filter notification, etc.	Simple Matters LLC, 2020
Vuzix Blade	Smart Glasses	Projecting display over the lens, calling a cab, setting timers, creating lists, watching, and listening the news or weather, controlling smart home devices, etc.	Vuzix Corporation, 2020
Bellabeat Leaf Urban	Smart Necklace	Step tracking, distance tracking, sleep tracking, stress tracking, etc	Bellabeat, 2020

and the degree of experience that they have had with similar devices in the past. Given the flexible form of wearables and the tendency for popular media to portray these devices used in a variety of fantastical manners, it is likely that people who have not used wearables before have widely different perceived affordances of wearable devices than those who have had actual experience with existing wearables.

3 Related work: Wearables for learning

Wearable devices, being persistently present on the user, provide the opportunity for situated learning, thus enabling learning in daily life settings (Bower & Sturman, 2015; Garcia et al., 2018). This allows for learning independent of user, place, and time. For example, a wearable can help a person to learn about the ingredients of a menu item from a different cuisine to decide if they would like it while ordering in a restaurant. Despite the potential of wearables to support learning in everyday life, there is hardly any commercial wearable that is characterized for that purpose, and the literature is still lacking in this area.

Our work addresses people's perception of wearable use for the purpose of learning in everyday scenarios. Much research has explored user acceptance and social acceptability of wearables, albeit at a general level and not specifically about learning or education. Such research is typically founded on the Technology Acceptance Model (TAM), Diffusion of Innovation Theory (DOI), or the Unified Theory of Acceptance and Use of Technology (UTAUT) (Niknejad et al., 2020).

For example, Yang et al. (2016), in an evaluation of user perception of wearable devices, found that perceived value (perceived usefulness, enjoyment, and social image), more so than perceived risks, drives adoption intention. In their study, a significant difference in wearable acceptance was observed between actual wearable device users and potential wearable device users. Perceived risks were found to be an important factor only for potential users but not for actual users. Also, perceived usefulness had a slightly stronger effect on perceived value than perceived enjoyment for potential users, whereas perceived enjoyment had a strong effect on perceived value for actual users.

Outside of perception and technology acceptance research, there has been work on different uses of wearables in education. We provide here a glimpse of the various ways in which wearables have been explored for use in learning contexts.

Many have explored the use of wearables for *formal learning*, in classroom contexts (e.g., Engen et al. (2018); Lee et al. (2016)) or school labs (e.g., Lukowicz et al. (2015)). For example, Lukowicz et al. (2015) investigated how smart glasses can be used to provide a stepwise guide to assist students in conducting a lab-based science experiment. Wearables have also been explored for *training*. For example, Vallurupalli et al. (2013) investigated the potential of google glasses for medical training. Their work entailed mock trainees wearing glasses to stream the medical task they enacted, allowing for live monitoring of their performance.

Spitzer et al. (2018) explored the use of smart glasses for *distance learning* through video streaming sessions. While a student is learning to perform a fine motor-skill task, the instructor can see the learner's point of view and at the same time can draw on top of the video to provide the student with additional context-aware information. Garcia et al. (2018) investigated the use of smartwatches for *insitu science reflection*, by allowing students to orally record their reflections on how their everyday activities relate to different science topics on a smartwatch.

Shadiev et al. (2018) explored the use of smartwatches for *language learning*. Participants who were English learners used a smartwatch to support their diary entries of outdoor interactions done in English. Reimann and Maday (2016) investigated the use of wearables as a platform to teach elementary school children to program and to engage in computational thinking. The children designed their own e-textile wearable objects. Leue et al. (2015) investigated the use of google glasses to assist learning in art galleries by projecting art-related information for viewers.

At a more general level, Bower and Sturman (2015) explored how educators perceive that wearable can be used in education. They found 14 perceived affordances, with the most frequently identified educational affordance for wearables being that they provide contextually relevant information (i.e., providing additional information on things present in a scenario). They also identified other educational affordances, like recording educational sessions or classes, simulation of challenging tasks for close-to-reality experience, better communication with teachers and students, increased educational engagement, first-person view, real-time supervision, hand-free access, and so on.

From a critical analysis of various projects on educational wearables, Lee and Shapiro (2019) list 5 ways that wearables have been used to support learning explored in prior literature: promoting personal expression; integrating digital information into social interactions; supporting educative role-play; providing just-in-time notification in a learning environment; and producing records of bodily experience for subsequent inspection, reflection, and interpretation.

4 Research methods

Our work seeks to obtain a broad picture of how people (wearable users and non-users) perceive that wearable can be used for learning, especially in everyday scenarios. The research questions that we addressed are:

RQ1: What are people's attitudes towards using wearables to support their learning in everyday life?
RQ2: Do people's attitudes towards using wearables for learning in everyday life differ if they have actually used a wearable before as opposed to if they have not?
RQ3: In what ways do people perceive that wearables can help them support their learning in everyday scenarios?

4.1 Study participants

This study was approved by the university IRB. The participants were recruited and compensated through the Amazon Mechanical Turk platform. The participants were compensated with a specified amount of money for their time and contribution. Bonus compensation was given if the participants fulfilled the criteria for submitting a good quality survey response. Bonus compensation was used to encourage quality completion. A total of 93 complete survey responses were obtained, out of which 70 qualified as quality responses. The filtering criteria that we used to check for quality responses are presented in the Data Analysis section. Only the quality responses were included in the dataset for analysis.

In the final dataset, we had a total of 38 female and 32 male participants. The average age of participants was 35.93 years, with ages ranging from 19 to 67 years. The participants were comprised of 39 White/Caucasian, 17 Asian, 5 Black/African American, 4 Hispanic/Latino, 2 American Indian/Alaskan Native, 2 multiple ethnicities, and 1 unreported. Fifty-eight of the participants were employed while 12 were students.

4.2 Instruments

We conducted an online Qualtrics survey, which was posted on the Amazon Mechanical Turk platform, to answer the research questions. The survey design aimed to capture participants' background, their experience with wearable devices, their perception of the use of wearables, and scenario-based question to explore the possible use of wearables for learning a variety of everyday life settings. The survey used both scale-based questions and open-ended questions to capture participants' perceptions. The study also had a 7-point Likert scale questionnaire to measure participants' acceptance of wearable technology for learning in everyday life. The survey consisted of 4 sections, each with one focus. Details of the survey design are described in the section below.

4.3 Survey design and study procedures

The survey consisted of 4 sections as follows. In the first section, the survey asked demographics questions. Then, a definition of a wearable device was presented, followed by examples of different wearable types (smartwatch/wristband, smart glass, smart ring, smart clip, smart necklace) presented with images, to ensure that respondents understood clearly what we referred to as wearable in the rest of the survey. Respondents were then asked about their prior wearable use experience, i.e., number and types of wearable devices owned. The second survey section contained open-ended questions pertaining to how the respondents would see themselves using wearables for learning. An example question was "Imagine you were to use a wearable device to help you learn about things in some manner. What kinds of specific situations can you imagine using it in?" Participants were asked to provide at least 3 use cases for this question.

In the third section of the survey, 9 fictional scenarios describing different potential everyday learning situations were presented to participants. Table 2 lists a few

Table 2 A few sample scenarios from the 9 fictional scenarios presented in the survey

Scenario ID	Scenario description
S1	"You are taking a walk in the park with your long-time friend chatting about your childhood memories. Further down the dirt path that you are walking on, you notice a squirrel biting on an acorn. This piques your curiosity. You happen to be wearing a wearable device during your walk."
S2	"You are a student in a Geology course, and you are sitting in lecture hall G320 for the first lecture of the course. The instructor is describing the water cycle and its impacts on weather patterns. The water cycle is a topic that you are somewhat interested in because you did a small project on it once. You happen to be wearing a wearable device in the class."

example scenarios. We expressly designed the scenarios to vary in terms of the formality of the environment setting, the state of social interaction of the user, the degree of familiarity of other characters with the user in the scene, and the user's mobility during engagement in the given situation. These variations represented common variations in everyday settings and possible constraints that the environment and context of use might affect how wearable can be used. The characterization of the 9 scenarios based on these dimensions is shown in Table 3.

For each of the 9 scenarios, participants were asked the following questions: 1) "Without restricting yourself to current functions and abilities of wearable devices, how can you imagine using the wearable device to support your learning in this scenario?"; 2) "What specific kind of wearable device do you think is the most suitable to use for the above scenario?". The objective was to allow participants to use their imagination as participants had different wearable experiences. Six options (commonly known forms of wearable devices) were given for participants to choose from: smartwatch/wristband, smart glasses, smart clip, smart ring, smart necklace, and others; 3) "Why do you think the wearable that you selected above is the best fit?"; and 4) "Imagine that you are wearing the wearable device that you chose for Q2. How would you use it to perform the tasks (from Q1)?".

Finally, in the fourth section, participants were asked to fill a questionnaire on a 7-point Likert scale about their level of technology acceptance of the use of

Table 3 Categories for all 9 scenarios

Scenario	Formality	Interaction	Familiarity	Mobility
S1	Not formal	With a person	Friends	On-the-go
S2	Very formal	Self in a group	Stranger	Static
S3	Not formal	Self	None	On-the-go
S4	Not formal	Self	None	Static
S5	Not formal	With person in a group	Friends	Static
S6	Not formal	With person in a group	Family	Static
S7	Somewhat formal	Self in a group	Stranger	Static
S8	Somewhat formal	With a person	Friend	Static
S9	Not formal	Self in a group	Stranger	On-the-go

wearables to support learning. We used the UTAUT scale for that purpose, which was adapted from Venkatesh et al. (2003). The scale consists of 8 subconstructs as follows (the definitions given here are those that we have already adapted for our case):

- Performance Expectancy (PE): degree to which an individual believes that using a wearable will help him or her to attain gains in learning.
- Effort Expectancy (EE): degree of ease associated with the use of a wearable for learning.
- Attitude Toward Using Technology (AT), an individual's overall affective reaction to using a wearable to support learning.
- Social Influence (SI): degree to which an individual perceives that important others believe he or she should use a wearable for learning.
- Facilitating Conditions (FC): degree to which an individual believes that an organizational and technical infrastructure exists to support use of a wearable for learning.
- Self-efficacy (SE): judgment of one's ability to use a wearable to support one's learning.
- Anxiety (ANX): degree to which a wearable evokes anxious or emotional reaction when it comes to using it to support one's learning; and
- Behavioral Intention (BI): intention to use a wearable for learning in future.

Overall, the procedures for the study were as follows: after selecting the HIT (Mechanical Turk term for a task) associated with the study on Mechanical Turk, the participant was shown an information sheet before the start of the survey. Proceeding to take the survey consisted of giving consent to participate in the study. Participants were free to exit and withdraw from the survey at any time. A maximum of 1 hour was given for participants to complete the survey, but participants took 29 min on average to complete it.

5 Data analysis

5.1 Data filtering

All survey answers were imported into a spreadsheet. Out of 229 survey responses received, there were a total of 93 completed responses, which were investigated further for their adherence to certain criteria to ensure quality. The filtering criteria used for selecting quality responses were as follows: (i) all questions on the survey were answered, i.e., the survey is complete; (ii) the overall completion time for the survey is > 5 min, i.e., participants took more than 5 min to complete the survey; (iii) the survey response is not duplicated, i.e., the same participants did not respond to the survey more than once; (iv) fewer than 5 responses to open-ended questions on the survey are irrelevant; (v) all answers are not the same, e.g., all ratings given are the same number, or the same text is copied over for multiple questions. After filtering the survey responses for quality, a total of 70 responses obtained, which were kept as the actual dataset for analysis.

5.2 RQ1: Attitudes towards wearables use for learning

Ratings for all the UTAUT items making up a subconstruct were averaged to give a single score for that subconstruct. An overall score for the entire UTAUT scale was also calculated for each participant by averaging all the subconstruct scores. For cases where the data distributions for the variables involved did not satisfy the normality criterion or discrepancies in sample sizes were too large, we used a non-parametric test. A one-sample Wilcoxon signed-rank test was conducted for each of the UTAUT subconstructs to see whether participants' ratings were significantly below or above the neutral point on the scale (4—neither agree nor disagree). The Wilcoxon signed-rank test compares assigned ranks based on median values.

5.3 RQ2: Difference between respondents with and without wearable experience

A variable was added to the spreadsheet to indicate whether a response was by a participant with prior experience with wearables (coded as 1), or without (coded as 0), based on the response to the survey question "Have you ever owned wearable devices before?". A chi-square test of independence was performed to examine whether preference of wearable type was significantly associated with prior experience with wearables.

Further, for participants with prior wearable experience, the scores of all the UTAUT subconstructs were averaged based on the type of wearable they owned. This led to the formation of 3 groups, namely the 'wearable experience with smartwatches', 'wearable experience with fitness trackers', and 'wearable experience with other kinds of wearables' groups. The 'others' group consisted of participants with experience with smart glasses, smart rings, and smart clips. These wearable types were not separated in their groups as the sample sizes were too small for each of them. Then the Welch's t-test or the Mann–Whitney U test (depending on whether the distribution met the normality assumption) was conducted to find whether respondents with prior experience with any particular wearable type rated the various UTAUT subconstructs differently than those without any wearable experience. The significance threshold for all tests was set at 0.05.

5.4 RQ3: Perceived uses of wearables for learning

All the survey answers involving qualitative data were coded by three coders. Coding was done one survey question at a time. At least 2 levels of coding (one descriptive and one categorical) were done for each question. Coder 1 went through 25% of the responses and assigned descriptive codes for each relevant unit in each response (with a unit being a phrase or a sentence). One response, thus, could contain more than one descriptive code. Codes generated were assembled into a coding scheme. The coding scheme was discussed with coder 2, who reviewed sample responses for the different codes in the scheme. The coding scheme was adjusted based on the discussion, and thereafter coder 3 coded the rest 75% of the responses using the modified final coding scheme. After coder 3 completed the coding of the entire dataset, the codes for all responses were reviewed by coder 1, and coders 1 and 3 met to discuss and resolve any discrepancies that arose. The categorical coding process was done jointly by coders 1 and 3 and was reviewed by coder 2. When required, more coding cycles were added depending on the complexity of answers obtained for a particular survey question.

6 Study results

6.1 RQ1: Attitudes towards wearables use for learning

Results of the Wilcoxon signed-rank test showed that ratings for all the 8 UTAUT subconstructs were significantly different from the test value of 4 (the neutral point on the scale). All the subconstructs had median values significantly higher than 4, except for Anxiety. Table 4 shows the median, Z value and p value of all the subconstructs. We note that anxiety is a negative subconstruct in the sense that the lower the score, the less anxious one feels about the technology.

6.2 RQ2: Difference between respondents with and without wearable experience

There were 18 participants with no prior wearable experience and 52 with prior wearable experience. Out of the 52 with prior wearable experience, 18 have owned one type of wearable device, 23 have owned two wearable devices, 9 have owned three wearable devices, and 2 have owned more than three wearable devices. Among the 52 that owned a wearable device, 50 owned a smartwatch, 48 owned a fitness tracker, 12 owned a smart glass, 3 owned a smart clip, 2 owned a smart ring, and 2 owned a smart necklace.

From the results of the Mann–Whitney U test, a significant difference was observed in the UTAUT subconstruct average scores only in terms of owned a smart necklace. From the results of the Mann–Whitney U test, a significant difference was observed in the UTAUT subconstruct average scores only in terms of social influence between respondents with prior experience with fitness trackers (Mean Rank = 27.63, Med. = 4.44, N = 42) and those with no prior wearable experience (Mean Rank = 37.19, Med. = 5.44, N = 18); U = 257.50, Z = -1.95, r = -7.75, p = 0.051.

Scores for the overall UTAUT scale, as well as for the 7 other UTAUT subconstructs, did not show any significant difference between any groups. However, for

Table 4 Example table Wilcoxon test results comparing UTAUT subconstruct ratings from the neutral scale value (4.00)

Subconstruct	Median	Z value	p value
Anxiety	3.25	-3.240	0.001
Effort expectancy	5.38	4.894	< 0.001
Attitude towards using technology	6.00	4.938	< 0.001
Self-efficacy	5.25	4.739	< 0.001
Performance expectancy	5.75	4.733	< 0.001
Facilitating conditions	4.75	4.687	< 0.001
Social influence	4.88	3.414	0.001

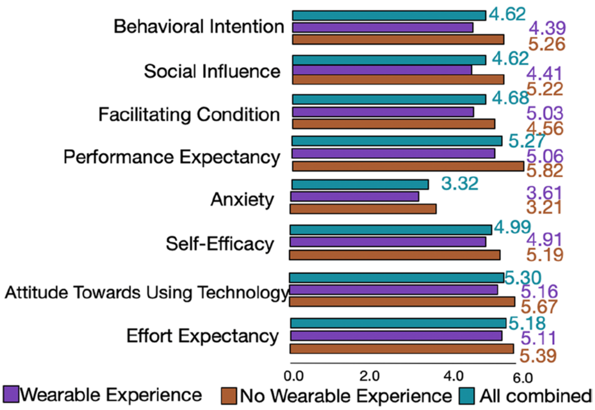

Fig. 1 Average scores of the UTAUT subconstructs for respondents with and without wearable experience

all subconstructs, a general trend was seen that respondents with wearables experience consistently rated the technology acceptance dimensions lower than their counterparts without any experience with wearables. This trend can be clearly seen in Fig. 1, which shows the mean values for each of the UTAUT subconstructs for the with and without wearable experience groups. Across all the fictional everyday scenarios presented in the survey, there was a significant association between preference of wearable type and prior wearable experience ($\chi 2$ (1, $N = 630) = 19.18$, $p < 0.005$). Figure 2 shows the percentage of times each wearable type was chosen across all the scenarios.

Table 5 shows the percentage distribution of each wearable type chosen by participants with and without prior wearable experience. Respondents with wearable experience preferred the smartwatch the most for use to support learning in the fictional everyday scenarios (61.1% of the times), followed by smart glasses (25.2%). For respondents with no prior wearable experience, even though the smartwatch and smart glasses were still the most chosen, the choice of wearable type was more spread out across the different device types. Types of wearable devices that respondents listed in the 'Others' option included, for example, smart clothing, smart pen, smart ear buds, etc.

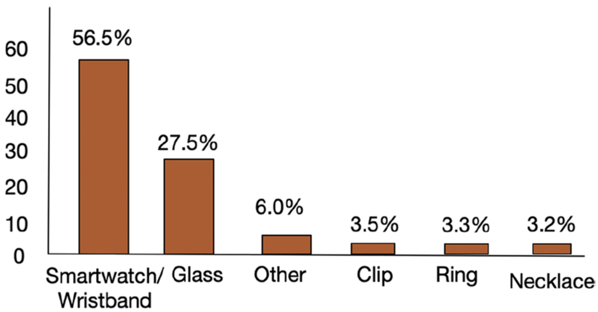

Fig. 2 The % of times a wearable type was chosen for all presented fictional everyday scenarios across all participants

Table 5 Cross-tabulation from chi-square test of presence of prior wearable experience by wearable type

Exp	% within	Glasses	Smartwatch	Clip	Necklace	Ring	Others	Total
No Exp	Count	55	70	7	5	9	16	162
	%Within No Exp	34.0%	43.2%	4.3%	3.1%	5.6%	9.9%	100%
Exp	Count	118	286	15	15	12	22	468
	%Within Exp	25.2%	61.1%	3.2%	3.2%	2.6%	4.7%	100%

6.3 RQ3: Perceived uses of wearables for learning

A total of 227 responses relating to the kinds of scenarios that people saw wearables being used for learning were collected from respondents. The responses were

Code	Definition	Count	% of all codes
Assistance category			
Navigation	Helps you to navigate to a place, finding distance and tracking locations	21	24.70%
Information lookup	Facilitates looking up interesting information or answering any question	16	18.80%
Internet and applicati	Allows one to connect to the internet and access its resources	13	15.30%
Searching store info	Assists in finding items or item's price in a store, or store schedule	11	12.90%
Apps	Helps by providing access to apps required in everyday life	6	7.10%
Planning	For planning and scheduling task	4	4.70%
Taking pictures	Allows one to take pictures	4	4.70%
Google search	Use wearable for google search	3	3.50%
Notification	Notifies or reminds you about any message or task	3	3.50%
Universal access	Assists the less abled to perform a task	2	2.40%
Media capture	Allows for the recording of pictures, videos or text, or assists in some other	2	2.40%
Activity/Task category			
Physical activity	While doing any physical task like running, hiking	23	47.90%
Everyday activity	While engaged in an everyday activity like shopping, commuting, setting ar	14	29.20%
Travel/tour	While traveling to a new place or in a tour at a historic location	5	10.40%
Reading/learning	While reading or self-study	3	6.30%
In idle times	When sitting idle or waiting	3	6.23%
Health category			
Fitness tracking	Tracking step count and other physical activities	18	35.30%
Heart rate monitor	Monitoring heart rate	11	21.60%
Sleep tracking	Monitoring sleep hours and sleep quality	8	15.70%
Health tracking	Tracking oxygen level, glucose level etc.	6	11.80%
Calorie tracking	Tracking calorie burned and calorie intake	5	9.80%
Monitoring blood pre	Monitoring blood pressure	3	5.90%
Specific locations category			
Work	Use wearable at the work places	10	28.60%
Recreational places	Use wearable at historic places, sites, etc.	10	28.60%
School	Use wearable at the school	6	17.10%
Store	Use wearable at the store	3	8.60%
Dine/party	Use wearable while dining out or partying	2	5.70%
Idle location	When at home or waiting room	2	5.70%
Sports/workout	Use wearable while at the gym or other sports, workout location	2	5.70%

Fig. 3 Codes of use scenarios for wearables for learning, ordered by prevalence in each category (% shows count of the code over total no. of codes in that category)

Code	Definition	Count	% of all codes
Characteristics			
Effective	Wearable responds effectively and accurately	10	25.00%
Advanced	Wearable possesses the most recent technologies	10	25.00%
Easy to use	Wearable is easy to operate, wear and carry	6	15.00%
Good quality	Material quality and overall quality of the wearable	5	12.50%
Aesthetics	Looks and style aspect of wearable	3	7.50%
Discreet	Wearable enables discreet and less intrusive operation	3	7.50%
Battery life	Wearable is durable in terms of battery life	2	5.00%
Affordable	Wearable is available at an affordable price	1	2.50%
Features			
GPS	Has inbuilt GPS	18	22.50%
Physiological tracking	Has sensors to track fitness and vitals like heart rate etc.	13	16.30%
Internet access	Ability to connect and access the internet	10	12.50%
Record media	Record or scan surrounding	9	11.30%
Time/timer	Has time/timer	6	7.50%
Microphone/speaker	Has microphone to record or interact	6	7.50%
Other	Other less common features	5	6.30%
Visual display	Has visual display through screen or projection	5	6.30%
WiFi/bluetooth	Has inbuilt wifi or bluetooth	5	6.30%
Large memory	Large memory space	3	3.80%
Functions			
Health tracking	Apps for health tracking	41	36.00%
Apps	Miscellaneous app to assist	26	22.80%
Voice assistant	Has voice assistant to interact vocally like Alexa, Siri etc	10	8.80%
Search engines	Has search engine like google	10	8.80%
Provide information	Ability to lookup information	7	6.10%
Connected to phone	Is connected to phone	6	5.30%
Time/timer	Shows time from different time zones, allows to set timer	4	3.50%
Notification	Notifies or reminds you about any message or task	4	3.50%
Text/email	Ability to send text, emails etc.	4	3.50%
Standalone	Able to function on its own, independent of phone	2	1.80%

Fig. 4 Codes of use scenarios for wearables for learning, ordered by prevalence in each category (% shows count of the code over total no. of codes in that category)

classified into 4 categories: (i) Activity/task: using the wearable device for learning concurrently while doing some tasks; (ii) Assistance: using the wearable device to help and support a primary task one is engaged in; (iii) Health: using a wearable device to learn about personal health; and (iv) Specific locations: using the wearable device in a particular setting for learning, such as using wearables at school. Each response category had a set of codes (Fig. 3).

Wearable use scenarios that the participants described were assigned a code in the *assistance* category 40.2% of the times; codes in the *activity/task* category were assigned 21.6% of the times; 22.5% for the *health category*; and 15.4% for the *specific location* category. Figure 3 shows the lower-level codes in each category with their frequencies and descriptions.

Code	Definition	Count	% of All Codes
Question-asking	Asking questions to get required information	359	56.30%
Capturing media	Capturing media like picture, video, text	93	14.60%
Displaying info	Visually displaying information in screen projections, etc.	44	6.90%
Hands-free interaction	Activating functionalities through voice or other hand-free means	43	6.70%
Health and fitness	Accessing information specifically about health and fitness	16	2.50%
Providing notifications	To be notified or reminded about any message or task	33	5.20%
Sees no relevance	Does not know how or why to use wearables	42	6.60%
Temperature	Finding or measuring temperature	8	1.30%

Fig. 5 Codes of how wearables can be used for the purpose of learning in given fictional everyday scenarios (% shows count of the code over total no. of codes across all scenarios)

With respect to the kinds of functions or features that people perceive wearables needing to support their learning in everyday life, 234 responses were collected. Three distinct response categories were observed in our coding of the responses: (i) Characteristics: wearables need a specific overall property, attribute, or quality; (ii) Features: wearables need certain distinctive or major functionality or sensor which can only be an in-built function; and (iii) Functions: what wearables need to be able to allow the user to do. Similar to the coding of the use scenarios, each response category here had a set of codes.

Responses were assigned a code in the *characteristics* category 17% of the times, while codes in the *features* category were assigned 34% of the times, and codes in the *functions* category 48.5%of the times. Figure 4 lists all the codes in each

Code	Definition	Count	% of All Codes
Characteristics			
Attached to body	This wearable type is attached to body, so readily available and difficult to lose	17	5.40%
Discreet	Wearable is subtle in terms of appearance and interaction	30	9.50%
Ease and utility	Wearable is easy to use, portable, quick, responsive, makes sense, etc.	92	29.20%
Powerful and advanced	Wearable is powerful in performance, has more space, advanced processor, multipurpose, etc.	20	6.30%
Functions			
Internet and applications	Wearable has access to the internet, google, and other Internet applications	56	17.80%
Notification	Wearable provides notification in the form of vibration of light feedback	2	0.60%
Provide information	Wearable has access to information	8	2.50%
Record media	Wearable allows to record video/audio, click picture, record notes/text	27	8.60%
Time/timer	Wearable tells time and has timer	3	1.00%
Visual display	Wearable has a screen and provides visual display	20	6.30%
Voice assistant	Wearable has voice assistant, which can take command, audio input/output	24	7.60%
Others			
Does not know	Unsure of reason to choose this wearable or other codes which appeared only once	16	5.10%

Fig. 6 Codes for reasons to use a wearable for learning (% shows count of the code over total no. of codes across all fictional scenarios)

Code	Clip	Glasses	Necklace	Smartwatch	Ring	Other
Attached to body	0.0	0.0	0.0	8.8	14.3	0.0
Discreet	17.2	8.8	0.0	8.8	14.3	9.1
Does not know	3.4	1.5	0.0	3.1	4.8	36.4
Ease and utility	34.5	38.2	43.8	25.2	19.0	22.7
Internet and applications	6.9	19.1	0.0	20.8	19.0	18.2
Notification	0.0	0.0	0.0	0.0	9.5	0.0
Powerful and advanced	10.3	0.0	0.0	10.7	0.0	0.0
Provide information	0.0	0.0	6.3	4.4	0.0	0.0
Record media	13.8	11.8	25.0	5.7	4.8	4.5
Time/timer	0.0	0.0	0.0	1.3	0.0	4.5
Visual display	3.4	10.3	12.5	5.0	9.5	0.0
Voice assistant	10.3	10.3	12.5	6.3	4.8	4.5

Fig. 7 Prevalence of codes (as % of all codes for that wearable type) for reasons to choose a wearable type to support learning (see Fig. 6) across all given fictional everyday scenarios

category with definitions and frequencies. Participants were surveyed on 9 fictional everyday scenarios, varying on dimensions of sociality, mobility, familiarity, formality, with respect to wearable use for learning. Across all the scenarios, 8 codes were identified on ways that participants indicated a wearable can be used to support learning. These are listed in Fig. 5 with definitions and the percentage of times that each code was assigned across all the scenarios.

Reasons that participants gave for why a wearable is useful to support learning in the fictional everyday scenarios were primarily of two types: (i) Characteristics with 50.5% of codes; (ii) Functions with 44.4% of codes. The rest of the reasons given were coded as (iii) Others. The codes in each of the response categories are listed in Fig. 6, along with their definitions and overall frequencies. The prevalence of the codes is also presented by the specific wearable type that the respondents chose for the scenario in question in Fig. 7. The total count of codes for the smart clip was 29, smart glasses 68, smart necklace 16, smartwatch 159, smart ring 21, and others 22.

7 Discussion

This study investigated people's attitudes and perceptions of the use of wearable devices for learning in everyday life. **RQ1:** Acceptance of wearable technologies as learning support was assessed using the UTAUT scale (Venkatesh et al., 2003). Ratings for all the UTAUT subconstructs were significantly different from the neutral point (higher for positive constructs: Effort expectancy, Attitude towards using technology, Self-efficacy, Performance expectancy, Facilitating condition, Social Influence, Behavioral intention; and lower for Anxiety, a negative construct). The general positive inclination towards using wearable for learning can be due to prior experience with wearables and the technological advances which has added advanced functionalities to wearable devices. The results indicate that people are generally positively inclined towards the use of wearables for learning, which suggests that should future wearables be designed to be explicitly learning-oriented, user acceptance and the intention to use the wearables would potentially be high.

Most of our survey respondents (52 out of 70) owned wearable devices, with most not surprisingly owning a smartwatch or fitness tracker. Results showed that participants with prior experience with fitness trackers rated the importance of social influence differently that those with no wearable experience. Social influence is rated significantly lower by those with fitness tracker experience. The decrease in the importance of social influence with accumulated experience in a technology has also been observed in prior literature (Venkatesh and Davis (2000); Venkatesh et al. (2000) as cited in Venkatesh et al. (2003)). A possible reason is that if users are more aware of the actual capabilities of a wearable device, they begin wanting to use the device for intrinsic motivations (e.g., recognized benefits that the device provides) rather than for extrinsic motivations such as social influence. This may be more so with fitness trackers, as first, these are commercially available at mostly affordable prices compared to other wearable types and thus the threshold for accepting the technology based only on intrinsic motivation may be lower. And second, people may be more aware of the functions of fitness trackers at this point of time given their public popularity, leading to greater intrinsic motivation for their use.

RQ2: Prior experience with wearables is also significantly associated with one's preference of the type of wearables to use for learning. Respondents with prior wearable experience chose the smartwatch/wristband 61.1% of the times, and smart glasses 25.2% of the times, suggesting a much larger preference for these two form factors over other form factors (clip, necklace, ring, others) that have percentage numbers ranging from 2.6% to 4.7%. Conversely, while we do still see a preference for the smartwatch (34%) and smart glasses (43.2%) for those with no wearable experience,

the choice of form factors is more distributed over all of the form factors, suggesting greater open-mindedness towards wearable form factors to use.

RQ3: In studying people's perceptions of the use of wearables for learning in everyday life, a key principle that we adhered to in our survey design was to allow for responses that are as broad as possible. The purpose was to elicit what people even understand by using wearables to support learning in the first place. This was elicited through two approaches: through asking participants to generate use scenarios with reasons in an open-ended manner, and through surveying participants on a variety of specific given fictional everyday scenarios where wearables may be used for learning.

Results from these two approaches were mostly overlapping, so we discuss them holistically below. Our survey results show that people perceive a large range of existing features, functions, and scenarios of use of wearables to be part of learning. For example, using a wearable to find how to navigate to a specific location, to look up store and product information, and to schedule an activity are all tasks that current wearables can already support but that are perceived as supporting learning in everyday life. Most notably, the 'health' category of codes indicates that even the use of wearables to track one's health aspects is perceived as being part of learning as learning about oneself.

In terms of how wearables can specifically be used to support learning, across the two elicitation approaches that we used in the survey, the overlapping ways of use were for ‘question-asking’, ‘capturing media’, ‘displaying info’, ‘providing notifications’, and ‘health and fitness’. From our review of prior work, common ways that wearables have been investigated for use to support learning in the literature are to provide step-by-step instructions (e.g., Spitzer et al. (2018)), to provide contextually-relevant information (e.g., Garcia et al. (2018); Leue et al. (2015)), to enable capture of one’s thoughts and environment (e.g., Vallurupalli et al. (2013)), to facilitate communication (e.g., Spitzer et al. (2018); Bower and Sturman (2015)), and to provide just-in-time notifications (e.g., Lee and Shapiro (2019)). Ways of wearable use for learning from our survey responses seem to generally align with these prior works, except for ‘question-asking’ and ‘health and fitness’.

The use of wearable for learning in daily life for question-asking was mentioned the most (56.3% of all codes in fictional scenarios responses, and 18.8% in open-ended use scenario responses). Asking information implies using a wearable to get information by asking specific questions, depending on whatever things are present in the environment piquing users’ curiosity. This is similar to how wearables have been used to provide contextually relevant information in prior work, e.g., providing extra information about an artwork that one is observing at a museum (Leue et al., 2015), but in prior work, the stimulus is typically predefined. In the case of everyday life scenarios, it is important that the extra information provided is based on the users’ in-the-moment interests. In fact, Mills et al. (2014) mentioned information seeking as a main form of informal learning. Hands-free interaction is also frequently quoted in participants’ answers. This code refers to the use of wearable to support learning while the user is simultaneously doing another task. Interaction through wearable can be triggered without much involvement of fingers or hands like gesture or voice-based interaction. This provides another support provided by wearable for insitu learning while engaging in everyday tasks. Participants also mentioned using wearables for learning about one’s health and fitness. Again, this reflects people’s broad conceptualization of what learning encompasses. In prior work, the use of wearables to support health has been extensively studied (e.g., Custodio et al. (2012); Canhoto and Arp (2017)), but the work is typically not framed as supporting learning.

The other wearable use codes echo manners of use present in the literature. Capturing media, the second most frequently mentioned use of wearable for learning, implies using a wearable device to record video episodes of events or lectures, take pictures of things of interest, and record textual information. This is like how wearables have been commonly used to enable the capture of one’s thoughts and environment in prior work. Displaying info has been commonly studied in prior work in terms of, for instance the wearable displaying step-by-step instructions to students performing a task (Lukowicz et al., 2015). And similarly, providing notifications has been observed in the literature as part of facilitating communication between students and teachers about new assignments, questions, etc. (Bower & Sturman, 2015; Spitzer et al., 2018).

Reasons that we found from the survey for why participants believed a wearable is suitable to support learning resonate very well with commonly cited characteristics of wearables in theoretical work. For instance, Motti and Caine’s (2014) list of 20 factors of wearables (wearability, subtlety, comfort, ease of use, contextual awareness, etc.), and educational affordances identified in the literature (e.g., by Bower and Sturman (2015)). However, prior theoretical work on wearables has typically identified the properties of wearables as a general class of devices.

Our survey shows that there are nuances in the properties that people perceive as important for wearables for learning based on the wearable type. Ease and utility, and access to the internet and applications were top reasons across all wearable types. Besides these, top reasons given specifically for smartwatch use for learning were that it can be powerful and advanced, in the sense that it can utilize the latest technologies (this is not always the case for all wearable types since the processing power of some wearable types are constrained by their form factors), and it is attached to the body, and therefore difficult to misplace compared to other wearables. A common reason for the use of smart glasses was the ability to record media. Top reasons for smart clip use were the discreet nature of the wearable, and the ability to record media. Use of smart necklaces was justified through the ability to record media, and to either have a visual display (surprisingly) or a voice assistant. And for smart rings, reasons given focused on the wearability and discreet nature of the wearable form factor.

In conclusion, from our survey results, we infer 5 main points as key take-aways for future research on wearables for learning. First, investigations into how wearables can be practically used for learning are worthwhile enterprises given people's positive outlook on the matter, and further work in that area is warranted. Second, the state of wearables that are currently available to the public (and thus, which people have experience with) influences how prospective users would approach new innovations on wearables for learning use. This influence can be manifested in terms of user motivations (why users would want to use the wearable) and device form factors (the specific kind of wearable type they would want to use). Third, wearables are to some extent perceived to already support learning or at least to have the capabilities to do so in their current state. However, they are not seen as dedicated learning support devices. Fourth, prior and current work on the use of wearables for learning are aligned with people's perceptions, except that greater focus should be placed on how wearables can be used to support question-asking in everyday life. And fifth, instead of seeing wearables only as a general class of devices, people have specific ideas of why different wearable types are useful as learning support, and thus specific wearables should be designed accordingly.

8 Study limitations

We acknowledge that the survey responses obtained were highly dependent on the participants' understanding of wearables and what they could imagine with respect to wearables. However, given the diversity of our participant pool, we are optimistic that we captured a sufficiently large scope of possible understandings and imaginations. Furthermore, it is likely that with new advances in wearable technologies being released to the public, people's attitudes and perceptions towards wearable use may change. Nevertheless, we believe that our study provides a valuable contribution, even if only as a call to catalyze research in wearable use for everyday learning, because as we mentioned before, work with this specific focus is presently relatively scarce.

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Authors' contributions Neha Rani contributed to literature review, study design, data analysis, paper writing.

Sharon Lynn Chu contributed to project conceptualization, study design, paper writing.

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Data availability Data is available to the authors and if needed can be requested from the corresponding author.

Code availability There was no specific application developed for the study.

Declarations

Ethics approval Study was approved university's ethics board, the institutional review board. IRB#: IRB201900971, Title:Understanding the Potential of Wearable Technologies to Support Learning was approved as exempt by Behavioral/NonMedical Institutional Review Board, FWA00005790.

Consent to participate IRB approved informed consent form was provided to the participants, and consent was obtained prior to the study. Participants were informed that their participation is voluntary, and they can decline to participate, or withdraw consent at any time free with no consequences.

Consent for publication All the authors were consented for publication and are fully aware of the content of the paper. I and my co-author have provided correct information to our best knowledge and provide consent for this publication.

Conflicts of interest/Competing interest On behalf of both the authors corresponding author states that there is no conflict of interest.

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