Beyond the Pocket: Preparing a Study on the Variations of Wearable Device Location

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ABSTRACT

Wearable devices have become ubiquitous in our daily lives, constantly collecting and analyzing data based on our activities. However, what these devices measure and, therefore, the accuracy of algorithms using this data can be influenced by the device's placement. For instance, a smartphone in a handbag might not track steps as accurately as one in a trouser pocket. The varied locations in which individuals wear devices is underexplored. We intend to conduct a cross-sectional study surveying the most common ways people wear and utilize wearables in their daily lives. We expect the results of this study to influence how research and industry use the sensor data produced by wearable devices, ultimately leading to more precise algorithms that produce satisfying results for a more diverse set of users.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; • **Hardware → Sensor applications and deployments**.

KEYWORDS

Internet of Things, Human Computer Interaction, Wearables, Study

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1 INTRODUCTION

Wearables have become increasingly prevalent in our everyday lives, as shown by the roughly 6.92 billion people, that use smartphones [15]. Encapsulating a plethora of devices worn directly on or loosely attached to a person, wearable technology [5] is used in various ways and kept on different body parts, depending on the type of wearable and its intended purpose. Some of the most common devices include smartphones [15, 10], smartwatches [6], fitness trackers [5] and medical wearables [5].

The choice of how and where to wear a wearable device depends on the device's functionality, comfort and user preference. For instance, a fitness enthusiast may wear a fitness tracker all day, while someone who wants discreet notifications might prefer a smart ring. Additionally, healthcare professionals may recommend specific wearables to be worn on particular parts of the body for medical monitoring.

However, it has been shown that the device location has an influence on algorithm performance [3] as those devices are used as scientific measurement tools [8, 3].

In our work we intend to answer the questions of (1) which types of wearables are worn by which groups of people and for what purpose, and (2) how and where are wearables worn, are they worn as intended?

To conduct an in-depth analysis of the proposed questions collecting a representative dataset from a bigger and more inclusive group of people is essential. However, in the past, researchers concentrated mainly on the medical or cultural aspects of carrying wearables. As their work aimed to answer more restrictive questions related only to specific groups, their used survey methodology differed from our proposed approach.

We propose to conduct a survey answering these questions, with the goal to produce reliable data that can be used to inform research (e.g human activity recognition - HAR) and production of software solutions incorporating how these devices are worn. As wearable technology continues to evolve, new forms and styles of wearables may emerge, providing even more options for users to choose how and where they want to incorporate technology into their daily lives. The results of our survey will help to align wearable research with the way users interact with the devices.

2 RELATED WORK

In 2007, Cui et al. [2] presented the results of the biggest survey examining where phones are carried throughout the day. The authors distributed questionnaires on the streets in a total of eleven cities and nine different countries. They collected the responses of more than 1500 participants. However, they mostly focused on identifying the main factors affecting the way smartphones are carried and how they are decorated depending on the country and did not consider how wearing behavior would influence the internal sensors of these devices.

In a 2014 paper, Szyjkowska et al. [12] analyzed the risk of subjective symptoms of 578 mobile phone users in Poland. This meant that their group of participants was limited to the population of one country. Additionally, they limited their pool of participants to people between the ages of 22 and 44. Which does, therefore, not entail a complete societal overview. The authors concentrated on the possible existence of mobile phone utilization affect on the human health which lies strictly in medical field of interest, omitting technical aspects.

We identified two additional studies dedicated to investigating the medical implications of close proximity between smartphones and the human body. In the first study, the authors chose 197 women between the ages of 15 to 40 as participants and investigated if the various radio-frequencies and electromagnetic fields have a negative effect on the female anatomy [9]. Although there was no significant correlation between health problems and wearing smartphones, they found a statistically significant correlation between the position participants carried their phone in and the age of the subject. In the second article, researchers conducted a study with 356 men between the ages of 18 and 72. Their goal was to identify the existence of a correlation between the position men carried mobile devices and their risk perception of radio frequency electromagnetic field exposure [14].

A further study examined the wearing behavior patterns of college students regarding smartwatches and analyzed the factors influencing them [6]. They selected 50 college students as participants and made them wear smartwatches for 203 days analyzing temporal wearing patterns and investigating the reasons behind those temporal patterns through data analysis and interview questions. As a result of the study, three groups of smartwatch users were identified based on their daily wearing patterns: work-hour wearers, active-hour wearers, and all-day wearers.

In contrast to previous research, our focus extends to a range of devices, encompassing smartphones, smartwatches and other wearables. Furthermore, we intend to diversify our group of participants and include underrepresented communities in our research, as long as ethical and regulatory considerations permit. Additionally, we intend to make the questions available in various languages.

3 PROPOSED METHODOLOGY

To obtain a good picture of the distribution of wearables and how people interact with them we intend to conduct an online survey. Reason being, that it allows for fast, far-reaching and cost efficient distribution and efficient data aggregation.

We plan to utilize various distribution channels to raise awareness about our study and encourage as many individuals as possible to participate. To that end we aim to distribute it in universities and social media platforms like Facebook or X/Twitter. Moreover, we intend to collaborate with people from a multitude of countries to achieve a wider distribution and capture possible country-specific differences in regard to our questions. To make the survey more easily accessible for people less inclined to use social media or other online platforms we intend to distribute flyers in tactical locations in various cities.

3.1 Questionnaire

The survey consists of two parts, as shown in Figure 1. In the first part, questions are asked in blocks asking participants what the device they are using is and where it is worn (right arm, backpack, etc.). For each position in which a device is worn, participants are asked when it is worn that way (for example, during sports, during the day, always, etc.) and how tight it is worn in relation to the body (on a Likert scale).

Those questions are crucial to determine the way a person uses a wearable and how well the collected data will describe body movement. This is done for several standard devices, namely smartphones and smartwatches, while also providing the option to add additional ones that were not already asked using the recursive structure of our survey.

In the second part of our survey, demographic data is collected. This also includes information like handedness, level of education, country of origin, and disabilities, for example. Among the standard questions about, for example, age and gender, we also included queries about the place of upbringing not only in terms of the area's urbanization but also in terms of country of origin. We decided to ask these questions, as country of origin, region the participants live in, and cultural background may influence attitude towards wearables, their availability, and, by extension, their usage. Another piece of unusual information collected is the question about handedness, which may greatly influence the collected data in the case of some wearables. Disabilities can influence many aspects of a person's life, from behavior to mobility, and naturally, this also impacts how wearables are used, which is why we also ask questions about possible disabilities.

We decided to use this recursive architecture mainly due to the diversity of wearable devices on the market. This way, we can extract all the information we require from our participants without them having to go through a long list of repetitive questions to find the specific devices they own and use. In contrast to that, our approach keeps the survey more manageable for participants, benefiting its completion rate.

3.2 Research Challenges

As described in research question (1), we intend to investigate which types of wearables are worn by which groups of people, and for what purpose. By conducting a cross-sectional study over an adequate population including multiple countries we believe that patterns will emerge that could give us interesting new insights into how humans interact with their wearable devices. This could allow us to find gender, age and country specific differences in interaction behavior and which devices are used in general. Furthermore, we

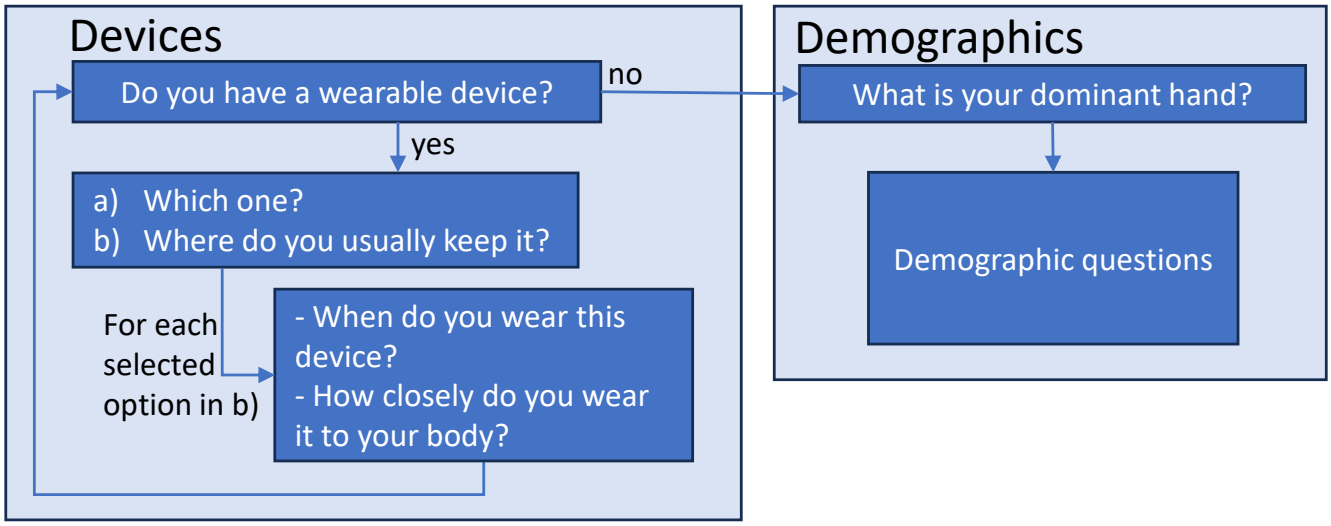

Figure 1: The general structure of the proposed questionnaire, depicting how we aim to get data for all wearable devices a participant owns without constructing an overwhelmingly large amount of questions.

could detect unforeseen and uncommon interaction behaviors not yet known in research.

How and where wearables are worn, as investigated in research question (2), can significantly influence the recorded sensor data. Because of this, figuring out how tight and in which position people wear these devices might lead to new insights shaping how sensor data is collected in the future. It could also drive researchers to develop algorithms which also produce good results for groups with less common device wearing habits.

4 DISCUSSION

As shown in Section 2, the amount of research conducted both recently and capturing a representative picture of the population of any country has been limited. The study closest to our goals, is from 2007 [2] the same year the first iPhone was introduced. Since then, wearable devices have become an integral part of daily live for a large percentage of the population [15], therefore a study with a broader scope is required to correctly depict how people interact with smartphones and other wearable devices.

From this survey, we expect a number of interesting findings. We may observe variations in device-carrying behaviors based on factors such as participants' country of residence, education levels, professional backgrounds, genders, ages, and more. This could allow researchers and industry to make better products in consideration of the groups they want to help with their devices.

Location of the device on the body has been a challenge for the algorithms [3]. As has been shown in the human activity recognition domain deep learning algorithms are able to achieve reasonable results for only few or single device [4, 7, 13]. However, those algorithms perform differently depending on the sensor's location on the body [3, 11]. Using our dataset as a resource would inform researchers about devices placement on the body, number of device per user and user behavior, allowing them to adapt and improve their model, leading to a more robust result grounded in the real-live behavior of the potential user base. As the domain independence also brings its challenges [1, 11], our survey aims to highlight the variations between user groups (age, gender, etc.) and, by doing this, promote the refinement of algorithms for real-world applications.

5 CONCLUSION

We believe that the effort of undertaking such a survey would be acceptable since the results could significantly impact on how researchers and industry use sensor data produced by wearable devices. By showing how and where the real-world use and the lab-conditions differ, our results could inform the ways in which data is collected to train or create algorithms and generally allow for more closely real-world inspired research setups, which would directly translate into a higher usefulness for humans. We plan to make the collected data available to public in one of many online repositories so the results of our survey could be used by researchers around the world.

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