From Perception to Participation: Rethinking Research on Phantom Vibration Syndrome through Citizen Science and Smartphone Technology

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Abstract — **The phantom vibration syndrome (PVS), a pathology not fully understood, primarily garners attention from medical research. However, a better understanding would allow engineering implications also to emerge, particularly in tactile interface design. In this article, a novel approach utilising smartphones and citizen science is introduced as a new research avenue. A preliminary trial involving 22 volunteers demonstrated an approx. 70% prevalence of PVS, while also uncovering potential challenges in app development and validation. Despite these hurdles, smartphone apps potentially offer scalability and facilitate citizen science engagement, rendering PVS research conducive to broad participation. Collaboration across medical, engineering, and citizen domains is advocated for achieving deeper understanding and effective solutions.**

Keywords— phantom vibration syndrome, citizen science, smartphone, human system interaction, human computer interaction, tactile interface

I. Introduction

In scientific literature, the phantom vibration syndrome (PVS) refers to the sensation of vibration, such as from a smartphone, even when the device has not vibrated. While research investigates the underlying causes of PVS, its existence renders it a relevant subject within the domains of human-system interaction, human-machine interaction, and human-computer interaction. To develop reliable tactile interfaces that users cannot confuse with phantom vibrations, a better understanding of PVS is needed.

Within the framework of this article, an approach will be proposed to contribute to PVS research by utilising devices such as smartphones as tools for exploration and initiating discussion on whether this approach could be viable for citizen science projects. Consequently, the article will be structured as follows: an initial introduction to PVS, succeeded by a brief overview of citizen science. Subsequently, the motivation behind suggesting the use of electronic devices in PVS research will be expounded upon, followed by the presentation of a preliminary implementation. Finally, the ensuing discussion will delve into various considerations and perspectives.

II. Phantom Vibration Syndrome

According to anecdotal evidence from the internet, the first appearance of PVS was in 2003, when an article titled "PVS" was authored by Robert D. Jones and published in the New Pittsburgh Courier [1]. Since then, the syndrome has been corroborated in studies. PVS is known to be referred to as hypovibochondria and is often mentioned in conjunction with the Phantom Ringing Syndrome (PRS), also known as ring-xiety [2], [3]. Studies have shown that the prevalence of PVS ranges from approximately 28% to 90% in test populations[3], [4], [5].

PVS creates a problem in interface design, as different design approaches can make the user more or less susceptible to PVS, and high incidence of PVS will lead to the interface being rejected along with the system it was supposed to support. Similarly, a better understanding of PVS may enable the design of interfaces which may be intuitively differentiated from PVS.

Due to the nature of PVS, research on the topic is published in domains such as (social) psychiatry, neuropsychiatric disease and treatment, medical and health sciences, environmental research and public/community health, nurse education, and human behaviour. Current research indicates that PVS can be correlated with high stress levels, anxiety, depressive symptoms, and psychopathology [6]. Furthermore, PVS and PRS are likely to be associated with excessive technology use, a phenomenon referred to as techno pathology [7]. There remain many open questions which may only be answered by collecting large amounts of data, which itself poses a new challenge, which we address in this paper.

III. Citizen Science

The foundational principles of contemporary participatory science have been significantly shaped by the work of Irwin and Bonney [8], [9]. They were among the pioneers who coined the modern definition of citizen science (CS) as "science for the people" and "science by the people." The historical evolution of participatory science is explored in detail by Miller et al. [10]. The ongoing discourse surrounding the precise definition and formalities is currently being investigated by researchers such as Vohland et al., Haklay et al., Miller et al., and Strasser et al. [11], [12], [13].

While the phrases "science for/by people" effectively encapsulate the philosophy of CS, instances like SETI@home, which harnessed the computational power of citizens to analyse astronomical radio signals [14], may foster the misconception that CS is solely about outsourcing computational power and data collection tasks. However, it is crucial to recognise that in the contemporary understanding of CS, citizens can participate in all stages of research, including proposing research questions, suggesting methodologies and data analysis.

Due to the absence of a standard definition of CS, an overview of its understanding in this context is provided by referencing "The Ten Principles of Citizen Science" proposed by Robinson et al. [15]. These principles offer a foundational framework for understanding the scope and practice of CS and include:

1. Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding. Citizens may act as contributors, collaborators or as project leaders and have a meaningful role in the project.
2. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions or environmental policy.
3. Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence, for example, to address local, national and international issues, and through that, the potential to influence policy.
4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.
5. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes are.
6. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for. However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science.
7. Citizen science project data and metadata are made publicly available and where possible, results are published in an open-access format. Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this.
8. Citizen scientists are acknowledged in project results and publications.
9. Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.
10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data-sharing agreements, confidentiality, attribution and the environmental impact of any activities.

To lower the barrier for enabling citizens to become active in CS, internet-based platforms have been created. The landscape of such platforms is dynamic, and it is likely that several platforms per country have already been established. Instead of providing a comprehensive list of all platforms available at this time, only the platform https://eu-citizen.science/organisations shall be mentioned as an example [23].

IV. Advocating for a Novel Approach

A. Motivation

Although the existence of PVS has been substantiated, the primary data sources and measurements derive from patient files and surveys or questionnaires, as depicted in Table 1. While the utilisation of these instruments is deemed appropriate for exploring the incidence and prevalence of PVS, as well as its contributing variables, it might not be optimal for addressing questions that are of interest to developers of tactile interfaces. Such inquiries could include whether there is a means to modulate the vibration amplitude so that it can be distinguished from phantom variations.

B. Novel approach

In order to contribute to PVS research by gathering significant amounts of real-world data, it is suggested here that body-worn hardware devices with user feedback storage and vibration capabilities be utilised. These devices could be tailor-made, and programmed to determine when and how they should vibrate, potentially incorporating a user interface

Studies on PVS and PRS and their means of sourcing data		
Title of publication	***Method of data acquisition***	***Year published***
Prevalence of Phantom Vibrations and Ringing Syndrome, and its Association with Smartphone Addiction among Medical Students of Teaching Hospital, South India [4]	Survey	2023
Phantom phone signals and other hallucinatory-like experiences: Investigation of similarities and differences [6]	Survey	2023
The Frequency of Phantom Vibration Syndrome in Medical Staff: A Cross Sectional Survey [2]	Survey	2022
Assessment on prevalence and its factors on phantom vibration syndrome among UG and PG students in selected colleges [16]	Survey	2021
Investigation of the Role of Anxiety and Depression on the Formation of Phantom Vibration and Ringing Syndrome Caused by Working Stress during Medical Internship [17]	Survey	2020
The prevalence of phantom vibration/ringing syndromes and their related factors in Iranian' students of medical sciences [18]	Survey	2017
Studies on phantom vibration and ringing syndrome among postgraduate students [19]	Survey	2015
Possible association between phantom vibration syndrome and occupational burnout [20]	Survey	2014
Prevalent hallucinations during medical internships: phantom vibration and ringing syndromes [21]	Survey	2013
Phantom vibrations among undergraduates: Prevalence and associated psychological characteristics [5]	Survey	2012
Phantom vibration syndrome among medical staff: a cross sectional survey [22]	Survey	2010

Table 1 Overview of studies on PVS or PRS and the method of data acquisition.

for feedback (e.g., acknowledging when vibration is perceived), and possessing storage capabilities. An alternative to tailor-made devices would be the utilisation of smartphones, which, in principle, possess all the aforementioned features.

C. Preliminary implementation

To gather experience regarding the requirements and practical challenges associated with the implementation of the idea to employ smartphones as outlined above in PVS research, a student project was initiated. The development with its features is detailed below.

A native smartphone app for Android was developed. In line with the rapid development approach, the app is not made available in the Google Play Store; test-users must manually install it. Upon installation and initial launch of the app, users are presented with the terms and conditions outlining the app's purpose, its storage capabilities, and voluntary nature of the participation. Subsequently, users are prompted to respond to 12 questions (Figure 1, B). Clear instructions follow on how to register vibration sensations (Figure 1, D). The "configuration screen" (Figure 1, E) is then activated, allowing users to select a time interval during which the app is prohibited from initiating vibrations (e.g., to prevent disturbance during sleep or distractions in quiet settings, such as student examinations). From that point on, upon opening the app, users are greeted with a screen displaying a progress bar indicating the elapsed time of the 7-day test period and a round button for registering vibration sensations (Figure 1, C, Figure 2, A). To streamline the process, users can also register sensations by confirming a notification on the main screen (Figure 2, B) without opening the app. Within the configured time limits, the app randomly initiates vibrations using the standard vibration type predetermined by the operating system. This facilitates the subsequent assessment of user susceptibility to vibrations. For a sensation to qualify as a phantom vibration, it is imperative that within the last 60 seconds, neither the app nor any other apps have generated vibrations or notifications to prevent real vibrations from being registered as phantom ones. Additionally, if a user registers another sensation within 60 seconds since the last perceived vibration, it is counted as a single phantom vibration. At the conclusion of the 7-day trial, the registered data is stored transparently on the user's smartphone as a human-readable CSV file, devoid of any identifying information. Then this file is securely transmitted to a server for anonymised analysis.

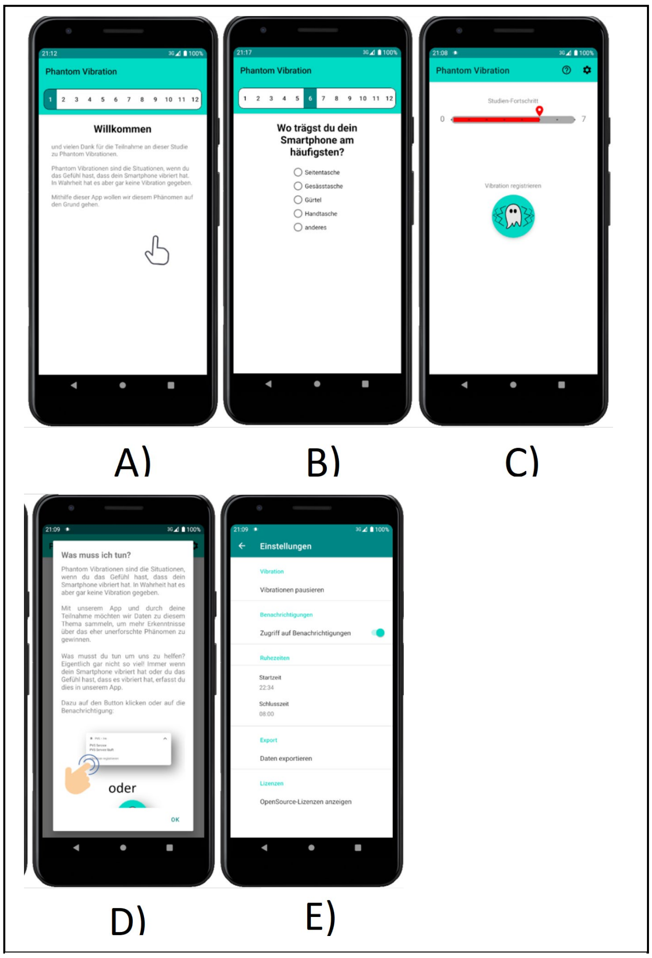

Figure 2 All available screens of the smartphone app. A)Welcome screen, B) questionnaire screen, C) main screen, D) user instruction screen, E) configuration screen

Results: 22 test participants installed the app on their smartphones and participated for 7 days each. Preliminary evaluation revealed that 16 participants experienced PVS, with 4 participants experiencing 6 to 10 sensations, and 5 participants experiencing PVS only once during the 7-day period. Regarding trial demographics, 8 participants were female, 14 were male, and their ages ranged as follows: 12 individuals aged 20-30 years, 3 aged 31-40 years, 2 aged 41-50 years, and 5 aged 51-60 years.

V. Discussion

The prevalence of PVS, estimated at approximately 70% by the preliminary study, falls within the range of approximately 28 % to 90 % reported by other studies [2], [3], [4], [5], [18]. However, the method introduced here for counting phantom vibrations has its limitations. One challenge stems from the app's limitation in tracking notifications from other apps, as it operates within the constraints set by the operating system. Consequently, it cannot be discounted that participants may have had apps installed that utilise vibrations as a standard feature in their interface, which are unidentifiable by the PVS app. According to the instructions

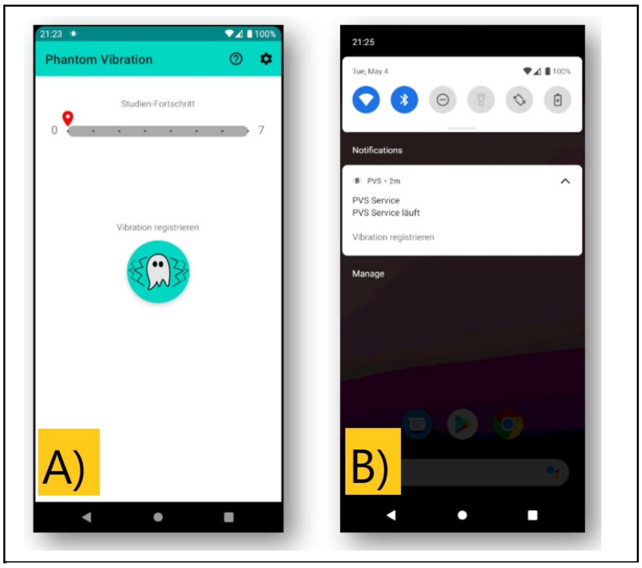

Figure 1 A) Smartphone app screen for vibration event registration. B) Registration via notification message.

provided to participants, they were required to register such vibrations, which were subsequently counted as phantom vibrations, potentially leading to false positive events. This means, that the 70 % prevalence represents the upper limit for true positive events.

To address this challenge, attempts were made to detect vibrations originating from the smartphone by utilising the accelerometer devices integrated into virtually all smartphones today. However, while it was feasible to detect smartphone-induced vibrations when the device was placed on a table, it proved impossible to detect them when the smartphone was worn. This was due to the accelerometer readings being influenced by normal everyday movements, making it difficult to distinguish the faint vibration signals from the "noise" generated by typical movements.

Therefore, further investigations into improvements are warranted. Solutions include, among others, monitoring changes in operating system capabilities with evolving versions, enabling options through jailbreaking, implementing tailored custom ROM installations, or attaching an external sensor (e.g., connected via Bluetooth to the smartphone app). Alternatively, addressing the issue through changes in study design is also feasible, such as providing participants with preconfigured smartphones and prohibiting the use of personal smartphones for body-worn purposes, or instructing participants to configure all other apps in use to prevent them from initiating vibrations. It can be anticipated that the implementation of the latter two options will impact participant adherence to the study design.

While the PVS prevalence found was considered to be the upper limit of true positive events, the question can be posed whether the actions needed to be performed to register a vibration, lead to cases, in which it was found to be too cumbersome. The implementation of the app, which presents a round button for registration, once the app is opened, represents the fall-back solution, in case all other procedures would not have worked. In such a case, to register a vibration, the participant needed to take the smartphone in the hands, unlock it, open the app and press the “register button.” To avoid losing registrations due to the cumbersomeness, the idea was to use the hardware buttons (on/off, volume up/down) in order to register a vibration. However, the limitations presented by the operating system prevented the implementation. Time constraints of the student project allowed not to explore alternative ways of registering vibrations, as e.g. by tapping a code with the fingers, like “three times shortly”, that could be reliably recognised by the accelerometers, or the use of switches of a smartwatch, or external Bluetooth switches. Instead, relief the participant from having the app open to register, after unlocking the phone, registration can be made via the notification.

Another limitation of the introduced approach is the uncertainty regarding the actual vibration amplitudes and vectors, which may vary depending on the make and model of a smartphone. This uncertainty can be addressed in the trial design by providing the same make and model to all participants. However, if the app were to be made available for download from an app-store, researchers would benefit from a database containing reference measurements of the vibration signal from all smartphones used in the trial. This would enable normalisation and better comparisons of the vibration events during analysis. However, this necessitates storing the make and model of the smartphone along with other data within the smartphone app, which may raise concerns regarding data protection.

Despite the technical limitations described, once such an app could be validated and its reliability determined, there is potential for offering new insights in PVS research. When the app is installed on the personal smartphone of the participant, an assessment of the participant's smartphone habits can be conducted. Additionally, such an app would enable more detailed tracking of phantom vibrations in the time domain, allowing for investigation into whether they are more prevalent during specific times (e.g., night shifts, circadian rhythm). Furthermore, various modulations of vibration signalling could be tested to determine whether there are discernible pragmatic vibration modulations or if a particular modulation exacerbates PVS symptoms. Additionally, such an app could incorporate integrated, validated instruments (e.g., questionnaires) deemed relevant by the researchers to inquire with the participant.

Due to the widespread adoption of smartphones, the availability of an app on various play-stores would facilitate the expansion of the test population. Researchers not accustomed to engaging with the public have the opportunity to familiarise themselves with the principles and methodologies of CS. Visibility for future projects could be enhanced through existing CS internet platforms, potentially leading to a positive impact on the size of the test population and the dissemination activities of the project.

In the context of PVS research, a CS approach could be integrated from the project's inception, with participants included in the participatory design process to define features of the app. Essential questions pertaining to requirements engineering, such as what information potential users are willing to share, could be addressed through a user-centred design process [24]. Involving participants in the design process not only ensures that the app meets their needs and preferences but also enhances the transparency and trustworthiness of the research process.

Installing an app provides a low-barrier entry for interested citizens to participate in PVS research. Utilising CS methodologies offers a pathway to engage with a broader and more diverse range of participants. This inclusive approach nurtures a sense of ownership and collaboration among participants, potentially resulting in heightened engagement levels. However, employing a CS approach does not guarantee the attainment of an unbiased population sample. It is possible that individuals who have already experienced PVS are more inclined to participate compared to those who have not. Additionally, precautions need to be implemented to detect malevolent users, who may be more inclined to join due to the anonymous nature of CS in this context.

Finally, it should be emphasised that the use of CS does not absolve researchers from their obligation to adhere to existing regulations. Special attention should also be given to regulatory and ethical compliance, ensuring e.g. GDPR conformity [25], [26], [27], [28], [29].

VI. Conclusion

PVS remains a pathology that is not fully understood, with predominant focus on research within the medical domain. However, PVS also holds implications for the engineering domain, particularly in the design of tactile (vibration-based) interfaces. Therefore, expanding understanding of PVS is deemed essential in domains such as human-system interaction, human-machine interaction, and human-computer interaction.

This article introduces a novel approach to PVS research, involving the utilisation of smartphones and citizen science methodologies, thereby enabling new avenues for understanding and addressing this intriguing phenomenon.

The rapid development of the smartphone app introduced here has revealed both challenges and potential within this approach. While smartphone technologies offer numerous useful features, their utilisation is often restricted by the operating system for security reasons.

The subsequent trial involving 22 volunteers demonstrated the proof of principle of this methodology, resulting in a PVS prevalence of 70%, consistent with findings from other research groups. However, the trial also identified potential shortcomings that need to be explored in future validation efforts.

Questions regarding user experience and usability concerns affecting the efficacy of the test protocol and the reliability of phantom vibration detection need to be addressed. Additionally, strategies are needed to accommodate the large variety of makes and models in the smartphone market. Despite the open challenges surrounding the development and validation of a smartphone app, this approach shows promise for exploring novel research possibilities and questions, such as automatically assessing smartphone usage behaviour and investigating the influence of vibration modulation to discriminate between real and phantom vibrations.

One advantage of employing a smartphone app is scalability. Once developed, such an app can be downloaded from app-stores and installed in large numbers. By aligning with the citizen science approach, interested and motivated citizens could benefit from a low-barrier entry to participate. For both citizen researchers and professional researchers, the potential for a large and diverse test group, likely more diverse than those reported in most scientific literature on PVS, makes PVS an ideal research topic for citizen science. Given the low barrier to joining PVS research and the cost-efficient scalability of the test population, coupled with its relevance to many smartphone users, PVS research appears tailor-made for citizen science.

In conclusion, the majority of studies in this field, as highlighted in the brief overview, rely on questionnaires. This article suggests the inclusion of smartphones and tailor-made apps to support PVS research. A closer collaboration between the medical domain, engineering, and citizens presents itself as a desirable approach.

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