Ethical Concerns and Perceptions of Consumer Neurotechnology from Lived Experiences of Mental Workload Tracking

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ABSTRACT

With rapid growth in the development of consumer neurotechnology, it is imperative to consider the ethical implications that this might have in order to minimise consumer harm. Whilst ethical and legal guidelines for commercialisation have previously been suggested, we aimed to further this discussion by investigating the ethical concerns held by potential end users of consumer neurotechnology. 19 participants who had previously experienced mental workload tracking in their daily lives were interviewed about their ethical concerns and perceptions of this type of future neurotechnology. An Interpretive Phenomenological Analysis (IPA) approach identified three superordinate themes. These related to concerns surrounding privacy, data validity and misinterpretation, and personal identity. The findings provide further validation for previous research and highlight further ethical considerations that should be factored into the commercialisation of neurotechnology.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **HCI theory, concepts and models**.

KEYWORDS

neurotechnology, ethics, neuroethics, mental workload

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1 INTRODUCTION

Devices that track brain activity in a healthy population is a market growing in quantity, quality, and investment. It is expected that commercialising neurotechnologies will provide a tool for improving health and wellbeing, productivty, entertainment, and education [9, 23]. Over the past 20 years, over $19 billion has been invested into neurotechnology companies [7] and patents being filed are only increasing[1]. With such acceleration in the market as a whole, it seems as though commercially available neurotechnology will be commonplace in the not-too-distant future.

Current available consumer neurotechnology start-ups include, for example, those that can track and manipulate sleep[2], track and help focus levels[3], or execute demands based on thoughts whilst gaming[4]. As well as for personal use, neurotechnologies used for monitoring others are also becoming available; for example, for teachers to monitor students' engagement in lessons [21]. The emergence of these technologies is growing, and considering the potential of brain tracking devices to essentially 'read' and 'write' people's brains [41] the possibilities are, arguably, endless.

But with this potential new way of living, there is huge potential for unintended consequences for this technology. The ethical side of neurotechnology should remain of the utmost importance when it comes to progress in its developments [9, 20, 23, 41, 42]. Whilst ethical issues and guidelines have been outlined (and is a current and active area of discussion in the community) for the development and production of neurotechnology [16, 20, 23, 41] , we wished to explore the ethical concerns and perceptions held by potential consumers.

19 participants who had experienced the tracking of their mental workload data in their daily lives were interviewed to gain insight into what should be ethically, socially, and legally considered when it comes to the development of neurotechnology from a consumer's perspective. We found three themes surrounding the fear of judgement and consequences, the negative effect that the data might have on personal wellbeing, and the sharing of data.

2 RELATED WORK

2.1 Real-World Brain Activity

Our understanding of cognition in the human brain has traditionally been developed by laboratory controlled studies using simple paradigms and stimuli [25, 28]. This work has formed, and continues to form, the fundamentals of many principles within cognitive neuroscience regarding cognitive processes and functional brain organisation [28]. However, a large body of recent research has made huge progress in studying brain activity in real-world environments [25, 28] due to developments in theories, signal processing techniques, computational power and brain mapping tools [28]. Whilst at an early stage, it is believed that taking experiments

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[1] https://sharpbrains.com/pervasive-neurotechnology/
[2] Dreem - https://dreem.com/
[3] Neurosity - https://neurosity.co
[4] NextMind - https://www.next-mind.com

out of the lab and into real-world environments may be a game changer for developing our understanding of brain activity, as the data is representative of the complexities and conditions of daily life [25, 28].

The brain imaging methods considered the front-runners for the measurement of brain activity in real-world settings are functional Near-Infrared Spectroscopy (fNIRS) and electroencephalography (EEG) [35] as they can now operate portably without physical constraints. fNIRS has relatively good spatial resolution compared to EEG [18] and EEG has relatively good temporal resolution compared to fNIRS [35], suggesting that the favourable method could very much depend on the study context. However, fNIRS is more robust against movement artefacts [35] and thus might be favourable in real-world settings with unrestricted movement. fNIRS can be used to infer brain activity by using near-infrared light to measure changes in blood oxygenation in the brain, which change depending on metabolic demand in the area [29].

2.2 Mental Workload

The ability to measure brain activity in the real-world is of extreme relevance to the neuroergonomics discipline [2, 35], which is the study of the human brain in relation to performance at work and in everyday settings [33]. A large research area within neuroergonomics is using brain imaging methods to measure mental workload [32, 34] with the aim of improving safety and performance at work and in life [31]. Mental workload is a defining factor for performance at work, as if the demands of a task exceed the resources available, performance errors can happen through overload [22]. Similarly, if there is too little stimulation, errors can also happen in the form of underload [45].

Thus, research has aimed to measure mental workload levels using neural measures in ecologically valid tasks. For example, fNIRS has been used to differentiate mental workload levels in realistic air traffic controller tasks [3], remotely operated vehicle operational tasks [8], and driving tasks [14]. Borghini et al. [4] outlines the ability of EEG in the measurement of mental workload in pilots during flight tasks. Whilst at an early stage, the number of brain imaging studies measuring mental workload in realistic and real-world tasks is increasing dramatically, and they are considered to be part of the next generation of mental workload studies that may enable the objective, continuous and non-intrusive quantification of mental workload in real-world environments [44].

Mental workload is not only relevant to performance in safety-critical situations, but performance in broader work scenarios too. For example, a lawyer submitting important paperwork, a banker making an investment, or an online sales worker trying to close a deal, are examples of office-type work where if the task does not remain within the worker's mental workload capabilities, costly performance errors might happen. In fact, Midha et al. [29] showed support for fNIRS in being able to differentiate mental workload levels in office-work type tasks. Outside of work, mental workload also remains a meaningful concept, with strong relevance to areas such as using medical devices at home, navigating using technology [38] or performing work-like tasks at home [11].

As mental workload is a concept so relevant to our performances, it can be argued that, now, with a more technological world, the ever more blurred work-life balance, and our tendency to strive towards optimising every aspect of our lives, mental workload should be considered from a life perspective instead of simply a work perspective. There is growing evidence that as well as being a defining factor in current task performance, balancing mental workload levels in our lives is also important for our wellbeing, daily perceptions, and performance on future tasks [30]. It is therefore apparent that tracking mental workload in our lives could be useful as a form of personal informatics, which is defined by quantifying aspects of our lives and changing or optimising behaviours based on the data that has been tracked [36, 37]. Indeed, a research aim in the passive brain-computer interface (pBCI) literature, which generally seeks to continuously monitor certain cognitive and emotional states in healthy subjects, is to use brain imaging methods to provide mental workload feedback to users [1].

2.3 Neuroethics

The consumer neurotechnology market (where products can be sold directly to consumers), which includes brain tracking devices, is rapidly growing in availability and investment [23]. But this growth in consumer neurotechnology comes with myriads of ethical considerations that must be considered [9, 19, 20, 23, 41, 42]. Hence, neuroethics is a field that refers to a broad range of ethical, legal and social issues that have emerged through progress in neuroscience [13]. Giordano [17] describes how the public anticipates ethical issues incurred by the speed and breadth of neuroscientific discovery, and that whilst the future is full of possibilities for insights into our cognition, there is also potential for misuse of information, misunderstandings and foul play.

Specifically in terms of consumer neurotechnologies, Kreitmair [23] has outlined seven ethical dimensions that should be considered in the development through to consumption of these technologies. These regard how the products must firstly be safe, without any medical or cybersecurity risk. They should be transparent, meaning the products must be validated in their performance. Privacy is the third dimension, where consumer data should be handled responsibly, such that data remains private. The technologies should be epistemically appropriate, meaning it should be considered that the quantification of brain data may interfere with how users see the world, potentially being less immersed in activities and more outcome driven. Existential authenticity should also be a consideration, where one's self-identity might be affected. The sixth dimension states that consumer neurotechnologies must be distributed fairly, without creating inequalities. Finally, in the absence of proper regulation, a working group of stakeholders should appraise the risks and benefits of neurotechnologies before they become available to consumers. If these dimensions are considered, Kreitmair [23] argues that consumer neurotechnologies would be able to meet their intended purposes of improving lives and experiences instead of having unintended consequences through unconsidered ethical implications.

Additionally, the UN's International Bioethics Committee have recently released (August 2021) a draft report on the ethical issues of neurotechnology [41]. As well as medically issued neurotechnology, the report considered consumer neurotechnologies. The authors outline that whilst there is potential for tremendous benefits,

neurotechnologies also hold the potential to damage individuals' privacy, deepen social inequalities and provide tools for the manipulation of individuals. They note that there are few regulations outside of those on medical devices used in research or the medical field, and recommend the introduction of 'neuro-rights' into law. This regards the rights of individuals to retain their integrity, mental privacy, freedom of thought and free will, the right to benefit from scientific progress and freedom of choice on matters related to the use of neurotechnology without any discrimination, coercion and violence.

Along a similar note, Ienca and Andorno [19] discuss how the development of consumer neurotechnology requires the emergence of new human rights, or at least the expansion of already established rights in order to address the emerging challenges of neurotechnology development. Indeed, Ienca et al. [20] included human rights as one of four identified areas that require proactive governance to ensure safe and responsible use of brain data outside of a medical domain, stating that brain data protection needs to be embedded into human rights in order to be included in the international normative framework. Binding regulation, where brain data is given its own category for mandatory data protection was another identified area for regulation. The third identified area was ethical guidelines and soft law, which regards how the collection and processing of brain data is governed. Finally, responsible innovation was the fourth area, which relates to the responsible collection and processing of data (such as validating the technology).

Whilst there is undoubtedly many current and required active and ongoing discussions about ethics and regulations in the development of neurotechnology, there is a gap in research relating to the ethical concerns and perceptions held by the end users of this technology. Thus, we wish to further research into the ethical considerations of consumer neurotechnology by investigating the ethical concerns and perceptions of potential consumers. In doing so, further ethical, legal, or social considerations of neurotechnology might be established, and the already established guidelines mentioned previously might be further validated. With the expected introduction of objective mental workload trackers that have the potential of providing several benefits to personal lives and work performance, this paper focusses on this neurotechnology; addressing ethical considerations at a relatively nascent stage of development is an aim in neuroethics [17]. It should be noted that focussing on one type of neurotechnology in this study was necessary to provide participants with lived experiences, but the recommendations provided by Kreitmair [23], the IBC Report [41], and Ienca et al. [20] described above refer to a range of neurotechnologies, and thus the findings of the current research will undoubtedly be applicable beyond the technology discussed.

In order to achieve the research aim of gaining insights into potential consumer perceptions about the ethics of a 'Fitbit for the brain' [43] device which could objectively track mental workload in daily life, qualitative data was obtained from office-worker participants. Based on the research outlined above, we hypothesised that concerns relating to privacy, data validity and personal identity would be identified.

3 METHOD

The study used an Interpretive Phenomenological Analysis (IPA) approach to understand participant's ethical concerns regarding the use of consumer neurotechnology in their lives. IPA is a qualitative approach that aims to understand how people make sense of their personal and social worlds in regard to their experiences and personal perceptions. [40]. Before general claims about the data are made, IPA harnesses an idiographic approach by considering each participant's data in depth. IPA is especially suitable for topics that are contextual, subjective, relatively under-studied and where issues relating to the self or identity are important [39]. A systematic approach for IPA has been outlined by Smith and Osborn [40], and has been adopted in this study due to the aim of understanding participants' perceptions about the ethics of neurotechnology.

3.1 Participants

19 purposive participants were included in the study after responding to advertisements through social media and email channels. The inclusion criteria involved participants who completed office-type work as part of their jobs, Android users, and no clinical history of anxiety or depression. 10 participants were industry workers, with professions such as a chartered accountant, a copywriter and a health economics manager; 9 participants worked within academia. Participant ages ranged between 21-45; 7 participants identified as female and 12 participants identified as male. Ethical approval for the study was obtained [RS-2019-R13]. All participants participated in two separate but related studies (described below) and received £100 as remuneration overall. Participants were provided with a series of documents outlining the measures of the studies alongside a few sample interview questions. Information about how participants' data would be protected was provided which also detailed their rights and risks. All participants provided informed consent in written form.

3.2 Procedure

In order to have an depth and meaningful discussions during the data collection, it was important to us that participants had considered mental workload in terms of tracking and what it meant to them in their lives prior to being interviewed about it. Thus, the Monday-Friday the week before the interview data collection, participants were recruited for a study which tracked their mental workload levels. Each participant was provided with a materials sheet detailing an introduction to mental workload and advice to 'tune in' to what mental workload meant to them. Participants then were required to enter subjective mental workload ratings from Monday-Friday (based on the ISA scale [26]) every 30 minutes during working hours and 1 hour outside of working hours. Online and phone activity were tracked for the duration of the study and participants were also required to fill out questionnaires each day relating to aspects such as their mood and sleep. The week following, each participant took part in a semi-structured interview for between 1-2 hours about their perceptions of mental workload and mental workload tracking. The focus of the data for the present study regards the data about ethics. Participants were probed about their views on the introduction of commercially available neurotechnology which could objectively measure mental

workload levels. The interviews were guided by a pre-defined set of questions; the ethics topics related to data privacy, data sharing and mandatory tracking, but participants were probed on individual topics that they mentioned and encouraged to talk in depth and give any relevant examples from their time in the week-long study and general lives.

3.3 Analysis

To conduct the IPA analysis [40], the interview data was firstly transcribed verbatim. For each transcript, the lead researcher familiarised themselves with the content before noting down comments relating to first impressions or interpretations of the data set. The comments were either descriptive or interpretive and different ink colours were used to differentiate between them. These notes were then translated into codes which were classed as emergent themes after the coding process. Connections between emergent themes were identified and these were grouped to develop initial subthemes and superordinate themes. This process was repeated for each transcript. Previous transcripts were used to orient the analysis, but respecting divergences and convergences remained a priority throughout. A final set of superordinate themes and their subthemes were identified across the full set of data once all transcripts had been analysed. After the transcription stage, the data was worked on collaboratively by the first two researchers. In the data reported, participants are referred to by numbers, e.g. P6 refers to Participant 6.

3.3.1 Quality Assurance and Positionality. In the interest of good qualitative research practice, the guidelines outlined by Elliott et al. [10] were followed. Firstly, credibility of the results was ensured by the collaborative working process; all themes were reviewed and refined by the first two researchers. The data set is grounded in examples and examples of any data presented will be given; descriptive participant data will also be provided. The perspective [10] and positionality [5] of the researchers have been considered in terms of recognising that their personal interests and assumptions about the research area may naturally contribute towards their research approach and understanding the research outcomes [10]. All researchers were from the UK; 18 participants were UK based and 5 UK based participants were from South America, and one participant was from and based in India. Therefore, this research can be categorised as WEIRD[5] [27].

4 RESULTS

Three superordinate themes were identified (Table 1): 1) fear of the data, 2) the negative effect of the data on the self, and 3) the spectrum of sharing. The first thing to note about the data is that participants frequently made comparisons between this 'Fitbit for the brain' data and data collected from physical activity trackers, where the concerns expressed and points made were considered as similar or comparable. For example: *"I guess it's [tracking objective mental workload data] similar to the sense that like I wear my watch, my sports watch, literally 24/7 for the last three years that I've had it … you can have it track all your data and see how far you've been, see where you've gone to, the places you've travelled to and things like that. I enjoy that level of data."* (P2).

The passage above highlights that Participant 2 considers the level and type of data collected from their sports watch to be of a similar nature to the mental workload data that could be collected in daily life. This notion was apparent throughout multiple transcripts, and suggests that tracking brain data is considered a similar concept to tracking physical data.

4.1 Fear of the Data

The first theme presented regards participant's concerns about the judgements arising from the data and include the subthemes 1) fear of personal judgement, 2) fear of consequences, and 3) fear of inaccurate judgement.

4.1.1 Fear of Personal Judgement. Participants often reported that they were concerned about people in their lives viewing their mental workload data and making assumptions about them as individuals. This is demonstrated by Participant 2: *"I wouldn't want someone having that [personal MWL] information on like a daily or weekly basis and then them making criticisms off that basis."* (P2)

Participant 2 described their judgement concern in terms of being criticised based on their data. Participant 1 reflected on their opinion similarly in terms of their data being viewed by employers: *"It shouldn't be any concern of an employer or supervisor as to how hard I'm working if I can produce the results. My concern would be someone seeing it and then judging the workload based on their perception of their own workload."* (P1)

As well as describing their concern in a workplace environment, Participant 1 also outlined their concern surrounding their fear of judgement by friends and family members too: *"I don't think my friends or family need to see it cause I don't know what they'd think of the workload. They're like 'Oh a lot of high workload on Friday evenings 7-9, what are you doing?'."* (P1)

The passages above represent a common feeling of concern across the data set of being judged on a personal level by the mental workload levels that have been tracked in their lives. This applied to both a social and work environment and was perceived negatively.

4.1.2 Fear of Consequences. Another frequent concern from participants regarding the tracking of mental workload in their lives was the negative repercussions that might arise if their data was accessed and judged by people with authority in the workplace: *"They [the boss] could use it in the wrong way and use it as like a punishment. Like, 'You're not being very productive,' or like,'You can't cope with your new promotion,' or whatever."* (P13)

From the passage above it is apparent that Participant 13 is concerned about their data being used against them in the workplace to affect their position in the company. Participant 5 provided another example of this: *"I think I would be worried that workplaces might judge people by this sort of thing [mental workload data] and might discriminate based on that."* (P5)

As well as concerns relating to consequences in participants' places of work, Participant 15 described a situation in which the data could have negative repercussions even in the recruitment process: *"I'd have issues if it became a widely available thing because the data collected would be so accessible. Like in the scenario where*

[5]From their critique of HCI research: Western, Educated, Industrialized, Rich, and Democratic.

Table 1: Table showing the final superordinate and subthemes from the qualitative analysis.

Superordinate Theme	Subthemes
1) Fear of the Data *Describes concerns relating to data judgement.*	Fear of personal judgement Fear of consequences Fear of inaccurate judgement
2) Negative Effect of the Data on the Self *Describes concerns relating to the negative personal effects of data tracking.*	Being controlled by the data Data exacerbating negative states
3) The Spectrum of Sharing *Describes concerns and views about data sharing.*	What concerns? Controlled sharing for positive change It depends on the risk An absolute no

I'm applying for a job and the employer asks me for my mental Fitbit data because you know, in 20 years it's just become the norm - you attach your mental Fitbit results for the last week or whatever on your CV . . . I think it's not necessarily representative of how good of an employee you would be. I think a lot of people that would make great employees would miss out on a job just because their numbers aren't as high as the others." (P15)

So Participant 15 describes how the data being accessed by employers might have negative consequences for employment opportunities, as they believe the data might be used to make negative assumptions which then have negative consequences.

As well as concerns about consequences related to the workplace, participants expressed concerns about the data collected being exploited. This can be shown in the following passage: *"They introduced those watches to track your health and all that, and it's a great idea but it took, what, maybe a month before an insurance agency used that as a way of increasing premiums on you. So there's no limit to how much those kind of tools could be exploited for other things, like someone denying you a raise cause apparently your workload is not very high."* (P4)

So here Participant 4 highlighted a data exploitation concern relating to how mental workload data could be misused against individuals in terms of discrimination; participants also expressed a data exploitation concern in terms of companies taking advantage of the data through targeted advertising: *"I'm kind of relating that to the online activity you have. Like it has happened to me that I have talked to someone like,'Oh I'm thinking about buying a flight,' and then it just suddenly appears the ads on Facebook and on Instagram and all the things about flights . . . I don't know really why I'm worried, but I know that's the way it shouldn't be, that they have access to all the data and they can use that for their advantage."* (P8)

So whilst participants may not yet be clear how the objective brain data might be exploited exactly, it is clear from this subtheme that participants are concerned that it will be used in ways that is considered intrusive and discriminatory.

4.1.3 Fear of Inaccurate Judgement. Participants often reported how important context is for interpretating the mental workload data accurately, and were concerned that inaccurate assumptions might be made if the data is viewed by an external person without understanding the context. A passage from Participant 2 highlights this: *"I guess the worry would be that you get to the point of it [tracking mental workload] becoming mandatory for work and someone's regularly looking at it and analysing all your data, and then uses that as justification at work. I don't like that. I think then you'd get to the point of micromanagement and stuff . . . Whilst I like having that information for myself, I wouldn't want other people to look at it and make assessments off the basis of it . . . There's more to it than just a number, you know, like a number ranking or a rating, something like that. It's only half the story I guess. So it'd be useful for just you personally to have a look at, but if someone whose got no context looks at it, you know, something bad might have happened . . . There's no context for it."* (P2)

Participant 2 demonstrated concerns which regarded the importance of the context of the data. Participant 3 demonstrated the same concern: *"[I would be concerned] that it [the mental workload data] would be misunderstood or misconstrued because out of context you could make some assumptions about the data that may or may not be correct."* (P3)

As well as the context being important for understanding mental workload data, participants were also concerned that the data itself is complex to understand and hence can be easily misinterpreted by employers viewing the data: *"I think there is a lot of nuances with brain activity so there has to be a lot of understanding, conceptualisation and training to understand it. So I feel if we give this data to employers, to industries, they don't have the skills to understand this and I think they will make a simple use of the data; they will look for high levels,'Ok we are looking for high levels, high levels are good,' which is not true and yes that will be used against employees. I think it's a lack of proper understanding of the data, it's a lack of 100% relationship between brain data and the outcome we have in the work, and the potential of negative effects on employees."* (P11)

Here Participant 11 described a scenario in which employers have access to their employees' mental workload data yet are not equipped to interpret it correctly, which could result negative outcomes for certain employees. Similarly, concerns were also expressed regarding the effect of inaccurate data or inaccurate assumptions on those tracking the data for personal use. Participant 18 demonstrates concerns relating to inaccurate data: *"I think it [a mental workload tracker] would just need to be quite robust in terms of its science. So for example, Fitbits and lots of those devices have*

got cautions in them, so say the ones that take your pulse . . . they have to have threshholds so high that people who might be a bit tired cause they overdid it on a run don't just pitch up at A&E like 'I'm dying,' it's like, "No, just calm down have a glass of water." So I think this would have to be grounded in some really good sort of cognitive science to know some of the differences between high flow states and high anxiety states." (p18)

Participant 3 outlines concerns relating to misinterpretations of data: *"If something as well understood as heart rate can be misconstrued in a medical setting for my benefit then I think this sort of data [mental workload] could be misconstrued."* (P3)

From the passages above we can see common concerns surrounding how devices that track mental workload data might lack validity or remain open to interpretation. Participant 13 captured these concerns in one passage: *"Maybe it's hard for an app technology to fully understand how you are. I guess it would make assumptions and I dunno, it's technology isn't it, it's an app, it's like not like, you know what I mean, you might take things too seriously. Like a Fitbit for your body, you take it too seriously like,'Oh it's telling me that my heart is permanently, I dunno, too fast,' you take that too seriously and it might make you make big life decisions based on yeah, assumptions."* (P13)

So this subtheme describes the concerns expressed by participants about judging the data inaccurately which could result in negative outcomes. From the importance of context, to the inability to make correct interpretations, and lastly, as Participant 13 outlined, basing personal decisions on data that is either inaccurate or misinterpreted, these factors are all speculated to potentially result in negative outcomes for individuals.

4.2 Negative Effect of the Data on the Self

This theme describes participant's concerns about the personal effects that tracking this data might have. It includes the subthemes 1) being controlled by the data and 2) data exacerbating negative states.

4.2.1 Being Controlled by the Data. A number of participants reported feeling concerned that the data could result in individuals becoming obsessive. Participant 10 demonstrates this: *"One [concern] is if you become too obsessed with it and it becomes a fixation and you can't stop looking and tracking. I know people have done that with heart rate monitors, they're like,'What's my heart rate now? Oh my gosh it's 72, 62,' so you know you can get obsessed with it. So finding a way to make sure that doesn't happen would be a concern."* (P10)

The passage above outlines how Participant 10 feels apprehensive about the personal impact that tracking objective mental workload data might have on individuals in terms of displaying obsessive behaviour. They refer to knowledge they have about the experiences of people they know and their relationships with their physical activity trackers and draws similar concerns for the mental workload data being discussed.

Participant 19 also discussed their concern of being controlled by the data, and similarly draws upon comparisons of physical activity trackers: *"I think you've gotta be careful because if you are relying on it too much as a validation strategy for what you're thinking then it could have an adverse impact. For example . . . it might be that 'We've noticed your mental workload's been high for a long time' . . . There is an inherent danger of relying on it . . . You wouldn't hold any reliance on a fitness app, you'd only use it for support, and the same goes for a mental workload app."* (p19)

4.2.2 Data Exacerbating Negative States. Participant 18 provided a rich account, again based on their knowledge of their friends' relationships with their physical activity trackers, detailing their concern that tracking this data in our everyday lives might be unhealthy for some people with mental health difficulties:

"I suppose your only concern is if you've got somebody who if they have anxiety or if they have depression or something like that, are you giving them a rod to beat themselves with? So you know how some people they have a really negative relationship with their Fitbit, they're like,'I didn't close my rings today, I'm such a fat this and I'm disgusting that and I'm never gonna this and blah blah blah blah.' I have a few friends who just use it to beat themselves and it's very hard to watch, it's very hard to stop. So I think it's about if you have high mental workload . . . I think it's about how you share those messages whether or not it can be interpreted positively in a kind, reassuring way rather than,'My Fitbit says I'm having a mental breakdown,' so I think that's where your risks lie that when it flags, how do people feel when it flags? What do they do? Does it have coping mechanisms? Does it give you advice? Because otherwise you can just reinforce people and escalate their worrying about workload so then they feel like they've got more workload and less able to deal with it. I think that would be the difficult side of it to navigate." (P18)

From Participant 18's passage, we see a speculated comparison between their experiences of how physical activity trackers can exacerbate negative cognitive states, and how tracking mental workload data might result in the same difficulties amongst people with mental health problems. They outline their belief of how important it is to present the data in a way which can only be interpreted positively, instead of providing some people with *"a rod to beat themselves with."*

4.3 The Spectrum of Sharing

There were some stipulations as well as black and white views that arose from discussing the collection and sharing of data. The subthemes that emerged included 1) what concerns?, 2) controlled sharing for positive change, 3) it depends on the risk, and 4) an absolute no.

4.3.1 What Concerns? Some participants simply had no privacy concerns about their brain data being tracked in their everyday lives: *"I'm fully aware that I've got a digital footprint that is far flung, I see no real issue with it. In fact, I'm forever selling my personal data. I'm someone that will happily do, you know, surveys for things and no doubt give too much of my personal data and information but no, no issues."* (P16)

The passage from Participant 16 reflects a number of other participants who seem to have no concerns about their data being tracked in their daily lives. Participant 7 provides another example of this: *"I don't think I have that many issues. I don't have issues - like if you could get like the Neuralink implant tomorrow, if you could volunteer for a free trial, I would be like, 'Elon [Musk] put me one, I just wanna be part of the trend.'"*(P7)

4.3.2 Controlled Sharing for Positive Change. In regards to sharing their data with their workplaces, participants often reported that they would do so if they were in control of who could access it: *"I think I would be prepared to share it with some people but I'd like control over who I share it with, and that would not necessarily be my boss."* (P10)

Participant 5 also demonstrated willingness to share if in control of their data: *"I wouldn't want it shared with anyone unless I give my consent . . . Maybe if it allows you to have a better conversation with your manager or something like that to improve your experience or your quality of life, I think then it would be good. But again I think that should be an individual's decision."* (P5)

With several participants requiring control of who their data is shared with, the reasons for sharing their data emerged to be for the purpose of personal improvement or company improvement. Participant 8 provided an example of personal improvement: *"I know that he [supervisor] will handle the data like correctly and maybe that would help me to improve my productiveness."* (P8)

So Participant 8 would be willing to share their data to improve their personal productivity levels. Participant 16 also described how they would share their data for personal improvement in terms of reaching their potential: *"Particularly if you're being under utilised, for example, or your mental capacity is being under utilised unintentionally, then it [sharing data] might bring some benefit."* (P16)

The passages above show how participants would share their mental workload data for personal improvements. Participant 7 described the sharing of data for company improvement: *"Maybe it [sharing data with their boss] can drive the company. Especially now after the lockdown and quarantine periods, maybe they can get to know like, 'Ok this group of people are actually quite effective working fewer hours, they still get everything done,' maybe they can change the working hours or the working environments to actually benefit people in that sense. If they're really conscious and really people orientated, if they want people who aren't enjoying it or are unhappy and are struggling to meet deadlines, they can tell, 'Ok how can we help them? Because if we help them, we help the company,' so I like to think they would make good use of it."* (P7)

In the passage above, Participant 7 reflected on how sharing their data with the company might lead to changes of how the company operates and this might have a positive effect on the employees' lives.

4.3.3 It Depends on the Risk. When discussing the tracking of objective mental workload data in pilots, participants were widely more accepting of mandatory tracking in safety-critical jobs: *"I think if you're a pilot then maybe yes [mandatory tracking is acceptable] just because you have lives in your hands. It's not like you didn't submit an Excel spreadsheet that you were asked for."* (P8)

We can see that Participant 8 deemed the difference between safety-critical workers and office workers as significant for the right of employers to access their data. Participant 4 compared mental workload data to other performance checks that pilots are routinely subject to: *"It wouldn't be too dissimilar as someone checking that the pilot is not drunk before flying a plane and that would be very intrusive in many jobs, but for a pilot it's fine."* (P4)

So whilst the consensus was that mandatory objective tracking in safety-critical workers was more acceptable than office workers, it was also frequently reported that even in these areas of work, the data must not result in personal negative consequences for employees.

"I think the whole structure of how society operates around this type of high-risk jobs should change. As in not say, 'Well you're off the job and obviously you can take less than the other pilot so then I'm either going to fire you or just going to pay for, you know, you can only work three hours today rather than six . . . ' So, I think obviously that would again lead to some sort of discrimination. But if the data is used to better understand these limitations at the impersonal level, so it might end up that you can see that for 95% of the pilots five hours is too much usually, so then without pointing fingers at individuals you might overall change the policy of the company to, 'Ok no one ever has to work more than five hours,' or whatever that time is so that statistically you reduce that risk . . . So maybe the company should make decisions based on large data sets statistical decisions." (P5)

The passage above from Participant 5 reflects on how tracking mental workload in safety-critical jobs in the context of pilots should not be used on a personal level, but instead be used to make company improvements to improve the safety in these jobs. Therefore, whilst this subtheme outlines how the risk of the job affects how participants viewed the enforcement of compulsory tracking, it was still deemed important that the data should not be used on a personal level.

4.3.4 An Absolute No. Some participants were firmly unwilling to share their data with their workplaces. Participant 4 described their reasoning: *"Scientists yes [I would share my data] obviously, boss absolutely not because it shouldn't be to be shared . . . It could be used for good, like you could have a good boss saying, 'Oh my gosh, my employee's always at a four [high mental workload level], I need to do something before they crack down and kill themselves,' and that would be good. However, for each good boss doing this, you would have a bad boss saying, 'You're still at a two [low mental workload level] are you just not working enough? I'm gonna give you more work.' As long as the task gets done the mental workload shouldn't be tracked or it shouldn't be a concern."* (P4)

From Participant 4's passage, we can see that whilst potential positive outcomes of sharing the data were acknowledged, they believe the data simply should not be shared because of the negative outcomes that have the potential to arise. This black and white unwillingness was shown by a few other participants; for example, Participant 1: *"I wouldn't want an employer to have it. I don't think they should be able to see that kind of thing for various performance reasons, like it being used for review."* (P1)

5 DISCUSSION

Consumer neurotechnology is arriving, and we are largely unprepared. Literature is increasingly producing guidelines aiming to mitigate the negative implications that consumer neurotechnology will unintentionally bring [9, 19, 20, 23, 41, 42]. That research has generally operated by identifying gaps in existing ethical and legal frameworks that do not accommodate for the addition of consumer neurotechnology into the market, and discussions and guidelines are outlined in relation to this. We ran an empirical study, however,

which researched the views of potential end users of consumer neurotechnology; participants were not made aware of the current status of discussions and regulations, and this contributed to an uncontaminated insight into the ethical concerns and perceptions held by those who may be future end users. The aim of the study was to ground current guidelines in further evidence and investigate whether there are any further factors that should be considered in relation to the development of neurotechnology.

We hypothesised that our findings would relate to concerns regarding privacy, data validity, and personal identity, as these have been recurring concerns outlined by various authors [19, 20, 23, 41]. Indeed, these concerns were prominent in the analysis. Firstly, concerns about privacy were widespread across our findings, and issues relating to privacy are also perhaps the area given the most concern in previous research [19, 20, 41]. Specifically, as well as the explicit wish to keep their data private (from theme 3), theme 1 (*concerns relating to personal judgement, personal consequences, inaccurate data judgement*) and *sharing data if in control* (a subtheme from theme 3) all related to the concern of data privacy. This finding further validates previous research which outline major concerns relating to privacy [19, 20, 23, 41]. If privacy is regulated properly, many of the ethical concerns identified in our findings could be mitigated, enabling consumers to enjoy the many potential benefits of tracking their brain activity. Additionally, this finding is interesting as it provides insight into the daily applications of privacy concerns that consumers might have. This provides a different angle to what is commonly seen in the literature, where discussions tend to centre around how privacy should be approached (such as suggesting it should be treated in the same way as other sensitive personal data [41]), with less explicit links to experiences in daily living and the explicated implication in peoples lives.

Secondly, concerns relating to data validity have also been outlined numerously [19, 20, 23, 41]. It has been noted that a number of current consumer neurotechnologies have limited precision [19]. Our findings also outlined concerns from participants regarding the data being inaccurate, and decisions being made based on inaccurate data. This highlights the requirement for transparent and regulated claims about validity, so that consumers do not experience harm from misleading data.

Theme 2 (*negative effect of the data on the self*) related to issues surrounding personal identity. This has previously been outlined; for example, Kreitmare [23] described two guidelines relating to the self (firstly changing people's views of the world and secondly altering people's self-identity) and the IBC report [41] described how algorithms can dilute the sense of self due to helping to make a person's decisions. Our findings align with this as they regard to how the data may alter the self. The subthemes *being controlled by the data* and *data exacerbating negative states* both highlighted specific applications from participants' lives about how neurotechnology might negatively change the state of individuals. This is important if it will affect Mental Health (rather than help people as is often advertised) and again helps to ground previous research in further evidence, and suggests there needs to be regulations surrounding the presentation of data (discussed more below).

There were two findings from our data that appear novel. The first one relates to the use of neurotechnology in safety-critical jobs, where privacy was deemed less of a concern if mandatory brain tracking could increase safety. This indicates a distinction between workplaces regarding what may be acceptable for the way that data privacy is handled. Secondly, participants were concerned (*fear of inaccurate judgement*, from theme 1) that even if their data was transparent and valid, themselves or their workplaces may not interpret it correctly, especially as the context of the data is essential for its understanding. Proper regulations surrounding data privacy might again mitigate the effects of external individuals (such as workplaces) misinterpreting the data, but that does not counter the concern that the data may remain open to misinterpretation by whoever views it.

5.1 Current Status of Concerns

The technological progress we are seeing has been coined the 'neuro-revolution' by Ienca and Andorno [19], which is expected to follow in the footsteps of the 'genetic revolution' that reshaped some of our ethical and legal notions. Currently, however, no mandatory governance framework specifically for brain data has been established in supranational or international law [20]. The European Union's General Data Protection Regulation (GDPR) is legally binding and concerns regulations for how personal data must be handled, from collection to processing. However, even if brain data is considered as sensitive personal data, Ienca [20] noted how the GDPR in its current state leaves gaps for brain data vulnerable to breaches of privacy; they suggest regulations that consider brain data in its own category, which could protect against vulnerabilities that are unique to this type of data, as is the case already with genetic data [19, 20]. The lack of regulations around privacy for brain data are so severe that there are currently no safeguards to protect brain data from the same data-mining and privacy intruding measures that we see with other types of data [19].

In light of the finding from the current study in which participants viewed safety-critical workers as having less rights to brain privacy compared to other jobs and individuals in order to improve safety at work, this sparks a discussion about different regulation requirements for different consumers. It appears that it may be in our better interests to shape privacy regulations around circumstances, such as for those purchasing neurotechnology for personal use compared to safety-critical workplaces purchasing neurotechnology to monitor their employees. However, guidelines from the IBC Report [41] strongly recommended legislation which requires all employees to have the right to refuse the use of neurotechnology without being excluded or devalued. Our exploratory finding does suggest, however, that there is the potential that for certain situations (safety-critical), neurotechnology use could be categorised similarly to other required but intrusive measurements that safety-critical workers are subject to, such as drug tests. However, tracking brain data is complex, and if workers did provide consent for their data to be tracked, neurotechnology may access brain data that is outside of the users' awareness, meaning traditional informed consent processes may not be suitable for the use of brain data [41].

Regarding concerns about data validity identified in the current study and previous research [19, 20, 23, 41], there are stringent regulations around the use of medical devices (the EU's Medical Device Regulation, or approval from the US Food and Drug Administration), but most consumer neurotechnology companies avoid

classifying their devices as medical by marketing them for wellness, relaxation, and other non-medical purposes [42]. This means that they are not subject to the stricter regulations [20] and users are not guaranteed that the data is valid and representative of true cognitive function [9, 20]. Progress in enforcing responsible innovation is being made [15] as ideas surrounding its governance are being discussed (such as the suggestion of neurotechnology developers subscribing to taking a responsible innovation oath [41]), but regulations surrounding data validation have not yet been fully established.

Concerns relating to personal identity are perhaps more of a grey area when it comes to regulation as it relates more to the characteristics of individuals as opposed to the rights that each person should have. Participants in the current study drew parallels between physical activity trackers and cognitive activity trackers to describe their concerns surrounding personal identity by describing their experiences with the trackers and extending these to neurotechnology. Similar personal identity concerns have been shown to apply to physical activity trackers [12, 24], such as users feeling decreased enjoyment associated with their physical activity [12]. Neurotechnology could therefore explore the approaches taken in regard to physical activity trackers which aim to mitigate the effects of using the technology on factors relating to personal identity. It has been suggested that to mitigate compulsive, addictive, and distracted behaviour in regard to physical activity trackers, the technology could incorporate periods each day where access to quantified data becomes unavailable to users [24]. With physical activity trackers already arguably ubiquitous, however, it would be sensible for consumer neurotechnology to be attentive to the issues and solutions surrounding personal identity in the physical activity wearable field in order to account for these effects at an earlier stage of growth. Understanding these negative affects of tracking is especially important for technology that is advertised as helping mental health and wellbeing; neurotechnology could have the opposite effect especially if it is measuring cognitive activity that is directly involved in mental health conditions.

The concern relating to the misinterpretation of neurotechnology data identified in the current study appears novel and thus it is not clear whether there are active discussions in terms of identifying guidelines aimed at lessening the negative effects of this. Again it seems sensible to draw on the similar issues between consumer physical activity wearables and consumer neurotechnology, especially when considering newly established concerns. Choudhury et al. [6] outlined how misinterpreting physical activity data can negatively affect wellbeing by causing a sense of panic; this can also lead to seeking unnecessary healthcare that can put strain on health services. Due to the risk of negative implications arising from data misinterpretation, designing user-friendly interfaces has been strongly emphasised along with clear user manuals [6]. This is a simple and yet important consideration for the development of consumer neurotechnology. Indeed, an aim of our research involves investigating ways to effectively communicate mental workload brain data to users; the findings from the current study will help to emphasise stringent checks for potential data misinterpretation.

5.2 Limitations and Future Research

The study was valuable in the sense that it enabled real-world insights on a granular level from potential users into the ethical concerns and perceptions of neurotechnology. By using this approach, we were able to provide tangible evidence supporting several concerns that have been discussed based on robust theories, and provide a different perspective to raise further ethical concerns which may not yet have been considered. Indeed, the IBC Report [41] highlights the necessity to anticipate the effects of implementing neurotechnology by using scenarios where society and future technologies are imagined and how they will interact. However, by running an empirical study, we have approached the research from an HCI perspective, which may lack understanding and detail into the depth of the topics under discussion in the ethics field.

Based on our novel finding regarding the privacy rights of safety-critical workers, this perhaps raises more questions than answers. The result was only based on a small sample of office workers, which may differ to the opinion of other samples and those safety-critical workers who would be tracked. And if safety-critical workers did consent to tracking, the effect that tracking may have on performance should be considered. Therefore, whilst the finding certainly raises an interesting point for discussion, much more research is needed before being able to establish potential legislation that has both human rights and safety maximisation at its core. It should also be noted that the type of neurotechnology under discussion in the interviews was narrow, as only mental workload trackers were considered. For the design of the study that involved interviewing participants about their experiences, it was necessary to focus on a type of neurotechnology. Mental workload was chosen for its relevance and developments in neurotechnology, as outlined in the introduction. This narrow focus differs to what is commonly seen in literature concerning the ethics of consumer neurotechnology, which discusses issues associated with all types of consumer neurotechnology. Whilst this paper regards a certain type of consumer neurotechnology, the results should be generalisable to other consumer neurotechnology; this is supported by our overlapping findings to other research, as outlined above.

6 CONCLUSIONS

This study presented a novel empirical approach to understanding ethical concerns and perceptions surrounding the growth of consumer neurotechnology. To ground the interview discussions, people that had experienced tracking their own mental workload were probed about their views, which enabled insights into the concerns of potential neurotechnology end-users and examples of daily scenarios to which these concerns applied. The results relating to privacy, data validity, and personal identity provided further validation for concerns that are currently under discussion. The results relating to privacy in safety-critical jobs and misinterpretations of data highlight further important factors that should be explored further. With the introduction of mass consumer neurotechnology on the horizon, it is imperative that progress is swift to regulate its use in order to mitigate any unintended consequences and enable users to flourish.

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Data Access Statement: Due to concerns over protecting the anonymity of participants, a protected dataset is available for researchers only upon request, with suitable ethics already in place. This contains: anonymised transcripts of interviews.

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