Understanding the Ethical Concerns for Neurotechnology in the Future of Work

Wendy Martinez
University of Nottingham
Nottingham, United Kingdom
wendy.martinez@nottingham.ac.uk

Johann Benerradi
University of Nottingham
Nottingham, United Kingdom
johann.benerradi@nottingham.ac.uk

Serena Midha
University of Nottingham
Nottingham, United Kingdom
serena.midha@nottingham.ac.uk

Horia A. Maior
University of Nottingham
Nottingham, United Kingdom
horia.maior@nottingham.ac.uk

Max L. Wilson
University of Nottingham
Nottingham, United Kingdom
max.wilson@nottingham.ac.uk

ABSTRACT

Advances in automation and autonomous systems means that the future of work will involve even more cognitive effort. For those in already cognitively demanding work, many of us aim to optimise our effort and productivity to achieve more in work, and ideally to rest outside of work. Neuroergonomics research is concerned with how neurotechnology will help improve work to be manageable and safe, often in e.g. safety critical work, operators experience high demands and mental workload. Meanwhile, Neuroethics is concerned with the largely unregulated future of this industry, involving technologies that are not technically medical devices, but will involve invasive forms of personal data. This work aims to explicate the privacy, trust, and ethical concerns that workers have about employers using neurotechnology to manage their workforces. An online survey and themes drawn from interviews with factory and office workers are presented. We conclude by discussing these concerns and how they might affect the rapidly expanding neurotechnology industry.

CCS CONCEPTS

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

KEYWORDS

neurotechnology, neuroethics, future of work, employers, employees, privacy, trust, ethics

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1 INTRODUCTION

Over the last few decades, there has been a surge in the development of devices that measure brain activity outside clinical contexts, with the goal of focusing on healthy people [6]. As personal devices, these recent advancements in neurotechnology have the potential to boost people's lives by assisting them in understanding their mental health, focus, and productivity. These devices, however, have recently been introduced into the workplace with the goal of monitoring workers' cognitive processes and mental states in order to improve work performance, productivity, and workplace safety [17]. The discipline that studies the human cognitive processes in relation to performance in the workplace and in everyday settings is called neuroergonomics [36, 45, 57]. Because of the novelty of deploying neurotechnology devices into the workplace, there has so far been limited investigation into users' (especially employees') perceptions about the ethical and social concerns that may arise from the brain data collected. This work contributes to the growing field of neuroergonomics and neuroethics, by addressing the following Research Questions:

- RQ1 Are people interested in tracking their own mental workload (as an example of brain data)?
- RQ2 What are their attitudes and concerns toward the adoption of brain-scanning devices in their workplace?
- RQ3 What are people's concerns about their mental workload data being shared?
- RQ4 What are employees' attitudes and concerns towards future brain-scanning devices?

In order to answer these research questions, we adopted a mixed methods approach involving an online survey addressed to full-time and part-time workers, and semi-structured interviews of office and factory workers.

2 BACKGROUND

2.1 Workplace Monitoring and Surveillance

Workplaces monitoring and surveillance refers to employer's ability to monitor, record, and collect information about workers' performance, behaviour, and personal characteristics in real time [9]. Example grounds for monitoring employees are: to protect business' assets, assess work productivity, track performance, prevent and reduce criminal activities, promote adherence to behaviour

safety standards, and increase profit [54]. More specifically, employee monitoring is considered a neutral practice that is executed to capture work-related activities, such as review employee' performance, and check the achievement of set objectives [34]. On the other hand, surveillance methods use a range of tools and data (on work and non-work related actives) that could result in being intrusive and dystopian, as they can be applied to force the employee to adjust their behaviour accordingly. While there are similarities between the two, surveillance systems distinguish themselves from monitoring as they could flag greater ethical and privacy problems [44, 68]. These controversies normally arise when employers use surveillance systems to inquire into workers' lives outside working hours; when workers need to submit precise information about how they spend their free time; and when monitoring applications are used that affect levels of control, trust, and autonomy [9].

Monitoring and surveillance in the workplace usually encompasses three aspects: the use of personal data, the use of biometric data, and covert surveillance [9]. Conventional monitoring and surveillance systems include: monitoring of telephones calls, emails, keystrokes, GPS web usage, CCTV, psychometric testing, drug testing, and genetic testing [2, 9, 34]. Technological advancements like brain-scanning devices have broadened and revolutionised employees monitoring and surveillance systems allowing the collection of a perhaps more intrusive form of biometric data, brain data. In recent years, several companies worldwide have adopted neurotechnological devices to monitor their workers in the workplace. Some reported examples in the media, including Hangzhou Zhongheng Electric, Ningbo Shenyang Logistics, and State Grid Zhejiang Electric Power, have recently acquired brain sensor helmets to monitor the performance of their factory workers. Zhongheng Electric has stated that the use of "emotional surveillance technology" have increased productivity and a profit of $315 million[1].

However, despite the boost in profit, it is important to state that workplace surveillance have consequences for workers, such as impacting their well-being, productivity, motivation, and work culture. Previous studies have observed that a high level of monitoring system could negatively impact employees' job satisfaction [1, 2, 19], induce stress [1, 19, 39], decrease work productivity [42] and creativity [65]. In contrast, however, research has observed a boost in productivity using electronic performance monitoring [26, 31]. Aiello and Kolb [1] have suggested that the way in which monitoring is executed influences productivity. Because of the novelty of brain-scanning devices in the workplace, however, there is a gap in research in determining how the use of these devices affects work productivity and workers.

2.2 HCI and the Future of Work

The use of health tracking devices such as Fitbit and Apple watch in the workplace to monitor employees' personal health is not new. Companies are keen to adopt wearables in the workplace on the basis that healthy employees are more productive, resulting in lower healthcare costs [14]. Financial benefits and discounts are often incentives used by organizations and companies to reward employees who are more physically active and/or share their personal health data (such as steps, heart rate, and sleep pattern) with them and/or insurance companies [14]. As well as health data, recently there has been a growing interest in using emerging neurotechnologies to quantify workers' cognition and affective states in real time. The deployment of these devices is not just changing workplace dynamics but the entire relationship between workers and technology. A variety of research organizations and funding groups are focusing on emerging technologies that will drastically change the "future of work" including AI, robotics, and *big data* [13]. Notwithstanding, there has been a lack of research within the human-computer interaction (HCI) community on how neurotechnology is shaping the workplace, as well as the implications of this technology in the workplace from the employee's perspective.

2.3 Neuroergonomics

2.3.1 Mental Workload. Over the last three decades there has been a growing understanding of the cognitive mechanisms that underpin human information processing [17]. If previously the study of cognition was limited to clinical and laboratory settings, recent technological and neuroimaging advances are allowing the study of the brain in real-world settings [17, 58, 59]. In the discipline of neuroergonomics, the ability to study brain activity, in particular mental effort in real time in everyday contexts is critical [7] in order to improve performance and safety at work and in daily life [59]. Several theoretical bases have been used to study effort at work and in daily situations, including cognitive load theory [67], mental effort [53] and mental workload [72, 73]. Among these various constructs, mental workload (MWL) is one of the most studied variables for understanding human performance. Sharples and Megaw describe mental workload as the *"relationship between primary task performance and the resources demanded by the primary task"* [64]. As a result, if task demands exceed the cognitive resources available to the individual, an overload will occur, negatively impacting performance and increasing errors; this condition can also occur when task demands are low (underload), because there is insufficient stimulation for the individual to remain cognitively engaged with the task.

According to cognitive neuroscience research, the prefrontal cortex (PFC) is the brain region associated with mental workload [28] since it is involved in attention processes and executive control [61]. The posterior medial frontal cortex (pMFC) plays a key role in performance monitoring, action selection and adaptive behaviour toward task goal [55, 69]. This area is particularly sensitive to errors and failure to meet task goals [70]. Growing evidence are showing that high probability of task failure lead to the deactivation of the PFC, and this can cause poor performance [18]. Mental workload is studied in work settings to ensure that the operator can handle the job demands and that it is within their capabilities, in order to avoid negative performance results [64] due to tasks errors [38]. A substantial number of research are showing their interest in assessing mental workload in safety-critical jobs [4, 8, 17]. Mental workload is also relevant in office jobs [47] where if an employee's mental capabilities do not exceed task demands, performance can decline and errors can occur, for example an accountant with too much paper work on a tight deadline might feel overloaded and submit

[1] https://www.scmp.com/news/china/society/article/2143899/forget-facebook-leak-china-mining-data-directly-workers-brains

the wrong file. Mental workload is also a significant element in people's daily lives. According to research, balancing mental workload can increase not only performance in life and work contexts [48], but also wellbeing [71].

2.3.2 Measurements of Mental Workload. Within the field of neuroergonomics and HCI, the assessment of mental workload can be done based on performance (primary and secondary task measures [46]), subjective self-assessment (e.g., NASA Task Load Index [27]), psychophysiology (through pupil dilatation [22] and facial temperature [40, 41]) or neurophysiological approaches (non-invasive brain imaging and passive brain-computer interfaces [5]). The brain imaging techniques mostly used in neuroergonomics research to assess mental workload in control studies and in real-world settings are electroencephalography (EEG) [10] and functional near-infrared spectroscopy (fNIRS) [17] since the new generation of these devices are portable and comfortable, allowing the user to move freely without any physical restrictions. Companies like Emotiv[2] and Versus[3] are amongst the pioneers in offering headsets to be used beyond lab experiments. All this allows cognitive data or brain data to be acquired in the workplace through a range of these on-head, body wearable, and off-body techniques.

2.3.3 Use of AI to Classify Mental States. There has been a proliferation in the use of machine learning applications to classify mental workload [52] and other mental states [23]. Techniques like unsupervised and supervised data-driven approaches and support vector machines [3], as well as deep learning methods like convolutional neural networks [62] are showing promising results, in classifying emotional states reaching relatively high accuracies [33]. Although this technology is still in its infancy, it has already been deployed in real-world settings such as health, wellness and the workplace [23].

2.4 Neuroethics

Neuroethics is a branch of applied ethics that studies the ethical, social, and legal issues that have arisen as a result of breakthroughs in neuroscience and neurotechnology [20], as well as understanding how human free will and human experience are influenced [35]. Due to the novelty of neurotechnology there are limited regulations and governance, in particular for non-medical devices [30]. Because brain data are linked to consciousness, the centre of our being, personality, behaviour, and individuality, the information acquired by consumer neurotechnologies may raise legal, privacy, ethical, and societal concerns. Brain data, just like other personal data, is subject to normal data vulnerabilities, including hacking, manipulation, re-indentification, unauthorized access by third parties, digital surveillance, discrimination to mention a few [30]. Furthermore, several studies [24, 30, 37] have found that the rise of neurotechnology could jeopardise personal identity (defined as an individual's sense of self [24]) and agency (referring to the subjective awareness of one controlling their own actions in the world [51]).

Privacy, as one of the main concerns often raised about neurotechnology [24, 30], is a contested concept across different disciplines. In this study, we define privacy as the ability of an individual to restrict access of their personal information and personal affairs from others [49]. Controlling who gets access to particular personal information is an important component of being a free person; additionally, it has been suggested that privacy, in the sense of freedom from intrusion, is necessary for human dignity and well-being [21]. Goering et al. [24] identified key features of privacy that may be impacted by neurotechnology, including the intimate nature of brain data. In particular, research considers how gathering brain data can lead to the exposure of private and sensitive information, such as the disclosure of mental illness or a brain pathology [24]. Privacy breaches have become far more common in recent years, in particularly in the marketing and social media industries. Corporations now have the ability to collect vast amounts of data (e.g. sexual preferences, political and religious beliefs, social status) to selectively target information dissemination. As a result, sharing brain data has the potential to expose more people and do even more harm if it falls into wrong hands. For this reason, in order to protect brain data, many academics have proposed to merge brain data into human rights international normative framework [24, 30]. Ienca et al. [30] proposed to modify binding regulation, to give brain data a special category of personal data. These regulations should protect: brain data prior to analysis, brain data generated by non-medical neurotechnology devices, against third-parties related to consumer neurotechnology applications, and protect people's ability to make free and informed decisions about the sharing and collection of their own data. In addition, it was proposed to establish labour regulations to protect workers in case of the use of brain data in workplace settings, in order to avoid employers from monitoring and collecting brain data for productivity purposes and from firing workers based on the data collected. Furthermore, brain data collection and data processing should also be regulated.

Despite the rising ethical research into more regulated neurotechnology devices, there is a gap in understanding how users view such devices, especially when introduced in the workplace. Because the average working adult spends 40-70 hours per week at work [60], introducing neurotechnology that prioritizes workers needs is critical to ensuring a more happy workplace and, as a result, a happier life.

3 METHODOLOGY

We adopted a mixed methods approach to investigate worker's attitudes to the potential future of neurotechnology in the work place. We gained broader insight into perceptions, concerns, and acceptance of neurotechnology through an online questionnaire, and performed a deeper qualitative analysis of interviews to identify key themes, using the Moral IT Cards [15] as a way to ground discussion of speculative but near-future technology. Participants who took part in the survey declared living in the United Kingdom, other European countries, South Africa, Mexico, Chile, Canada and Israel. On the other hand participants who participated in the interviews were from the United Kingdom and Canada.

3.1 Survey

The survey consisted of an introduction which aimed to inform the participants about the purposes of this study, and a series of 10 questions to establish informed consent. The main part of the survey

[2]https://www.emotiv.com/
[3]https://getversus.com/headset

consisted of a mix of 25 quantitative and qualitative questions in order to develop better insights about participants' attitudes regarding brain tracking devices (see Tables 6-9 in the Appendices). The survey was divided in 8 sections: *demographic data; stress and mental workload; relationship with technology; tracking own mental workload; tracking physical activity vs tracking mental workload; tracking mental workload in the workplace; mental workload data sharing concerns; attitudes and concerns toward future neurotechnology.* The *demographic data* section focused on age, gender, occupation, job expertise, amount of physical activity, and relationship with technology. *Relationship with technology* was established in relation to the adoption of new technology (early adopters, early majority, late adopters, and laggards) [32].

A key challenge for the survey was to ground participants thinking in regards to what consumer neurotechnology can realistically identify. The *stress and mental workload* section began with defining these concepts, and a 5 point Likert Scale to address participants' stress and mental workload in their daily lives and in their workplace. The *tracking own mental workload* section contained multiple choice questions to understand participants' existing familiarity with neurotechnologies; their interest in tracking their mental workload; the purposes of using this technology (we used multiple answer and open-ended questions to expand on their interest, as well as 7 point Likert Scale questions to understand advantages and disadvantages of neurotechnology in people's daily lives).

In the *tracking physical activity vs tracking mental workload* section, multiple choices questions and an open-ended question were used to understand if participants tracked their physical activity, and explored their opinion regarding the differences between physical and mental workload tracking. For *tracking mental workload in the workplace*, a series of multiple choices, open-ended questions and Likert scale questions were implemented to understand participants attitudes, feelings, and concerns about the use of neurotechnology during recruitment processes, in their workplace, and to understand their opinion about which professions should make this technology mandatory.

Following this, the *mental workload data sharing concerns* section included a series of questions with 5 point Likert scales to evaluate respondents' feelings in regards to sharing their mental workload data with different parties (friends/family; non-work-related third parties; with employer to assess task difficulties; with employer for positive outcome in workplace). The *attitudes and concerns toward future neurotechnology* section involved a set of multiple choice and open-ended questions to understand people's feelings about future neurotechnology devices.

3.1.1 Distribution and Quality Checks. The survey was implemented using Microsoft Form, in order to safely store data within our university secure storage, and it was distributed using Prolific[4]. All the questions in the survey were mandatory and the data collected were anonymous. Two forms of data quality checks were put in place. First, simple attention checks were implemented on 2 questions, requiring people to tick specific responses in order to receive payment. Second, a more qualitative *understanding check* was added to the *tracking own mental workload* section, which included a specific explanation about three features that current neurotechnology devices could and could not do, followed by three true/false questions relating to these statements. Participants that answered these incorrectly were still paid, but their responses were excluded from the quantitative analysis.

In total, 171 participants filled in the survey, 20 were excluded for failing attention checks, resulting in 151 for the qualitative analysis. A further 59 respondents failed the understanding checks and were excluded from the quantitative analysis, resulting in 92 surveys analysed using quantitative methods. Participants spent between 10 - 15 minutes to complete the survey and were remunerated with £1.50 through the Prolific platform.

3.1.2 Survey Analysis. A mixed approach was used for analysing the surveys: some quantitative questions were used as independent variables in analysis and are presented as descriptive statistics; significance statistics were performed on the core quantitative questions, and qualitative questions were thematically analysed by all five members of the research team during in-person data sessions. The ordinal answers and answers to the questions formatted as Likert scales were converted into quantitative variables for correlation analysis, always with ascending numbers from low to high answers or negative to positive answers. None of those variables followed a normal distribution as tested by Shapiro tests, therefore Spearman's rank correlation tests were used to study the correlations of the dependant variables to the independent variables. The 5 % error threshold was chosen for significance levels following standard practice. The qualitative approach used for themes involved stages from Braun & Clarke's recommendations [12], but should be considered with a lighter touch due to the form of data collection and brevity of answers.

3.2 Interviews

3.2.1 Aims of the Interviews. The aim of the interviews was to gain a deeper insight into participants' opinions and concerns toward the adoption of brain-scanning devices in the workplace, in order to include a range of perspectives from both manual/physical and more cognitive forms of labour. The participants for the interviews were recruited through an advert posted on Linkedin and Facebook, as well as through word of mouth from participants. The recruitment criteria were individuals over the age of 18, employed in an office or factory/warehouse and with no history of mental health issues. In total 10 participants (5 office workers and 5 warehouse workers, 5 males and 5 females; age range 20-30 years old) were interviewed.

3.2.2 Interview Structure. The interviews followed a semi-structured approach. In particular, to ground the discussions and help to parameterise the space of discussion beyond their default thoughts, we selected a relevant sample from the Moral-IT and Legal-IT Deck [15] to present to participants for discussion. These cards were originally created to enable designers and developers to reflect and discuss the technology and products that they were creating. The cards are divided in four frameworks: *privacy*, *ethics*, *law*, and *security*, and each card include a title, a figure, and a provocative question (see the questions in Table 10 in the Appendices). We presented four cards from each framework (*privacy*, *ethics*, *law*, and *security*), as shown in the Appendix. By involving these cards,

[4]https://www.prolific.co/

the interview prompted participants to reflect more broadly on the legal, ethical, and social concerns in adopting brain-scanning devices in work settings.

The interviews were performed through Microsoft Teams. In order to allow the participants to visualise the cards, the cards were presented on a Miro[5] board, and screen shared to the participants. During the interview, participants were asked to pick 2 cards from each framework (*privacy*, *ethics*, *law*, and *security*), after having selected a card, they had to motivate their choice. In order to make the process clear to the participant, after having picked a card, the researcher moved the chosen card onto the dedicate discussion box. This was also done to allow the participant to remember the cards previously chosen. The interviews were audio recorded through Microsoft Teams and automated transcription was produced by doing so, which were then adjusted through manual transcription. The average time to complete the interview was around 25 minutes and participants received £10 remuneration for their time. The interview protocol was approved by the school's ethics committee.

3.2.3 Interview Analysis. The interview analysis was executed using thematic based analysis following Braun & Clarke's approach [12], in which a table containing the themes identified from the interviews and their respective codes was generated. Codes and themes were challenged in team meetings, as they were presented to the group, and analysis continued until data saturation and themes became stable.

4 RESULTS

4.1 Survey Results

52.2% of valid-data respondents were male, 46.7% were female and 1.1% were non-binary. 56.5% of respondents were between 18-25 years old, 40.2% were between the age of 26-45 and 3.3% were between 46-60 years old. The participants recruited were in full-time or part-time occupation from different levels of work experience: 35.9% were entry-level, 28.3% were intermediate and experienced, 5.4% were advanced and 2.2% were senior professionals. Their industry sectors are shown in Figure 1a. 39.13% of participants described their work as a sedentary profession, 43.5% stated to work in a moderately physical job, and 17.4% worked in a primarily physical role. Of these variables, age group mainly correlated with *willingness to share brain data in the workplace*, as well as *the feelings towards some of the evolutions of brain-scanning in the future*. These are presented as we reach those analyses.

To highlight the difference between stress and mental workload, in work and everyday life, we asked participants to rate each as low, medium, or high, as shown in Figure 1b. Our participants described their stress at work and in their personal lives to be largely similar, with around 20% describing it as low, 75% describing it as medium, and only 5% as high. Participants reported their mental workload differently, with 17.4% indicating that they had high mental workload at work, with 6.5% having low mental workload, and 76.1% with medium levels of mental workload. These findings indicate that participants have higher mental workload levels in their workplace compared to their daily lives. Respondents' stress at work correlated with their *attitude towards sharing brain data and mental workload in the workplace*, as well their *opinion towards the impact of brain-scanning in the workplace*, shown later.

4.1.1 Neurotechnology and Personal Informatics. 25% of respondents self identified as an early adopter (first people to embrace a new technology before general population); 62% stated to belong to the early majority (people that take their time to adopt a new technology, but willing to embrace it as long as it fits in their lives); 10.8% reported to be a late majority (people that adopt a new technology in reaction to peer pressure, or emerging norms and sceptical about new innovations); and 2.2% considered themselves to be part of laggards (last people to adopt an innovation).

We found that the responses to the adoption of technology in the questionnaire were correlated with variables including *brain data sharing at work and in the daily life*, *the perception of the impact of brain-scanning in the workplace*, as well as *the feelings towards the future of brain-scanning devices*, shown later.

In respect to participants' familiarity with neurotechnology, 51.1% of participants were not familiar, 44.6% described themselves as somewhat familiar, and only 4.3% were familiar with it. It is perhaps interesting, at this point, to note that nearly half considered themselves to be somewhat familiar with neurotechnology. However, it is important to note that participants knew what the survey was about before they took part, which means they were likely interested in this topic in the first place. The familiarity with neurotechnologies correlated to some answers amongst the *the brain data sharing in the workplace* questions, shown later.

When asked directly if participants were interested in tracking their own cognitive activity, 35.9% of participants were interested and 25% were very interested, only 4.3% were not interested. When asked for which main purposes (multiple choice allowed), most were interested in their stress and their brain health, but these levels are comparable to other options (see Figure 2a). When choosing to suggest alternative reasons, participants also stated that they were interested in using this technology for: curiosity, as lie detectors during crime investigations, and in the workplace as evidence to ask for a raise.

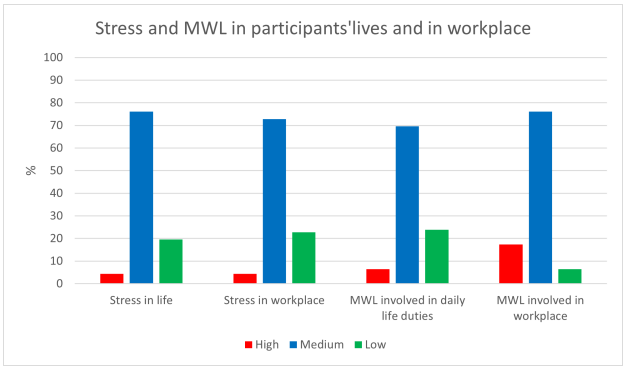
Respondents were also asked whether they thought the use of brain monitoring devices in their daily lives would have a beneficial or negative impact (see Figure 2b). 84.8% believed that technology can help them achieve a better work-life balance, 83.7% believe it can help them improve their productivity, and 80.4% believe it can help them improve their mental health.

We asked participants to consider how tracking cognitive activity may differ or be similar to tracking physical activity. Among the recruited participants 29.3% track their physical activity regularly. 75% of respondents viewed tracking their mental workload similar to tracking their physical activity. Table 1 shows a thematic clustering of the differences expressed by some participants in an open text box.

For *purpose*, participants focused on the differences between physical and mental health: *"I think that when you track your physical activity, your main purpose is to achieve a certain physical goal and, in order to do that, you need to track your results to knowledge your limits and to try to improve your physical condition, setting the bar higher and higher. On the other hand, when you track mental*

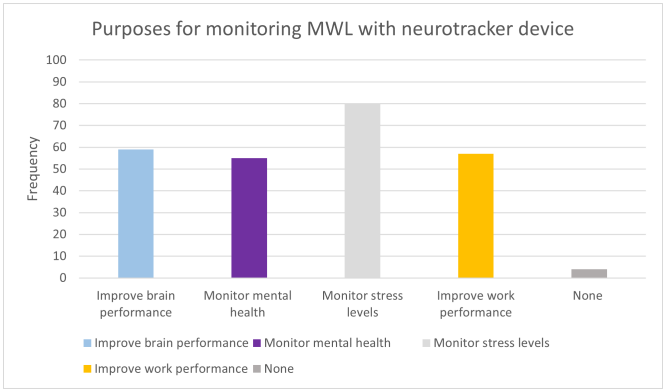
[5]https://miro.com/about/

(a) Wordcloud of participants' occupations

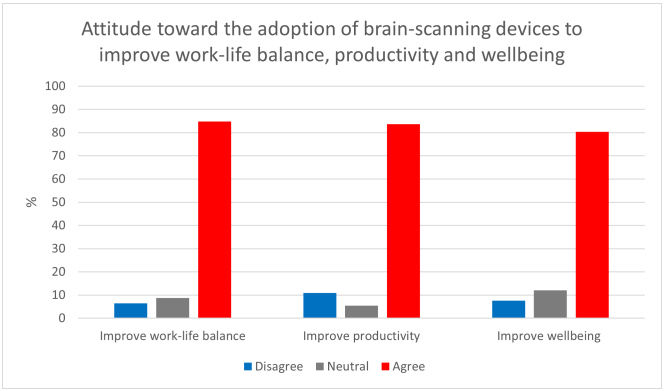


(b) Participants' stress and mental workload levels (MWL) during their daily lives and in their workplace

Figure 1: Participants' Demographics



(a) Purposes for measuring mental workload levels using a neurotracker device



(b) Participants' attitude in using a neurotracker device in their daily lives

Figure 2: Neurotechnologies and personal informatics

Table 1: Themes with respective codes from the open-ended question: *"What are the differences between tracking mental workload compared to tracking physical activity?"*

Themes	*Codes*
Purpose	Improve health in different ways
	Self-awareness
	Prevention
Concept	Mind and body are separate entities
Complexity	Devices
Control	Visible and Hidden
	Unchangeable
Intrusiveness	Intrusive tracking

workload, you're not trying to improve your mental abilities, increasing your mental capacities, you are just trying to achieve a stable peace of mind. In that way, you won't feel stressed and you will be able to know which tasks you can do" (P71). Participants typically saw the purpose for self-awareness, which in turn led towards goals of preventing poor mental health.

People understood the *concept* and *complexity* of brain activity to be different. *"Tracking mental workload means guiding your emotions and how you feel throughout the day. While tracking physical activity has to do with knowing how many steps you have taken in a day"* (P114). Complexity was considered in largely equal measures, between the newness of the technology, its accuracy, and indeed the complexity of different cognitive activities that they are trying to observe. Indeed, for *control*, participants highlighted that it is hard to control mental activity, and hard to observe something internally, where as physically performing activity is easier to action and observe. *"We can limit our physical activity, but with our brain and mental workload very often we can't limit being nervous or worried, we can't just simply stop like we can stop our body while running when we feel that we're too tired, tracking mental workload seems more complex to me"* (P69). For this reason, participants considered this internal observation to be *intrusive*.

4.1.2 Neurotechnology in the Workplace. Participants were asked to state their feelings while imagining a scenario in which a brain-scanning device was used during the hiring process for a job position. 60.9% of participants reported that they would feel uncomfortable, while 22.8% stated to feel comfortable and 16.3% were neutral. In respect to their feelings about adopting monitoring of mental workload in the workplace, 60.9% of participants stated to feel uncomfortable, 20.7% were comfortable and 18.5% were neutral.

The answers to these two questions correlated with 3 of the independent variables as follows: positive correlations with *familiarity with neurotechnologies* (p-value of 0.044 regarding the recruitment and 0.029 regarding mental workload monitoring in the workplace) and *technology adoption in general* (p-value of 0.003 regarding the recruitment and 0.013 regarding mental workload monitoring in the workplace), and negative correlations with *stress at work* (p-value of 0.005 regarding the recruitment and 0.018 regarding mental workload monitoring in the workplace). This means that being uncomfortable with the use of brain-scanning during recruitment and mental workload tracking in the workplace was linked to a low familiarity with neurotechnologies, a delayed adoption of technology and high stress at work. The correlation coefficients are reported in Table 11 and 12 found in the appendix.

Respondents were also asked if they would authorise their employer to monitor their mental workload during working hours. 44.6% said they would not allow it, 34.8% were uncertain, and perhaps interestingly 20.7% would allow it. Participants were invited to provide their thoughts on how brain-scanning devices in the workplace would affect their performance and productivity. As shown in Figure 3a, 52.2% stated that this technology would boost their productivity, while 32.6% believe that it would be counterproductive and 15.2% were unsure. This negatively correlated with *age* (p-value of 0.019) and *stress at work* (p-value of 0.003), and positively correlated with *adoption of technology* (p-value of 0.009), meaning that a belief that it would impact productivity negatively was linked to an older age, a higher stress at work, and a later adoption of technology in general. Tables 11 and 12 in the appendix report the correlation coefficients.

Trust between employee-employer was also investigated. 66.3% reported that this technology could have detrimental impact on this relationship, while 25% believe the opposite and 8.7% were neutral (see Figure 3b). This negatively correlated with *stress at work* (p-value of 0.002) and positively correlated with *technology adoption* (p-value of 0.001), meaning that a belief that it would impact trust negatively was linked to a higher stress at work, and a later adoption of technology in general (correlation coefficients can be found in the appendix).

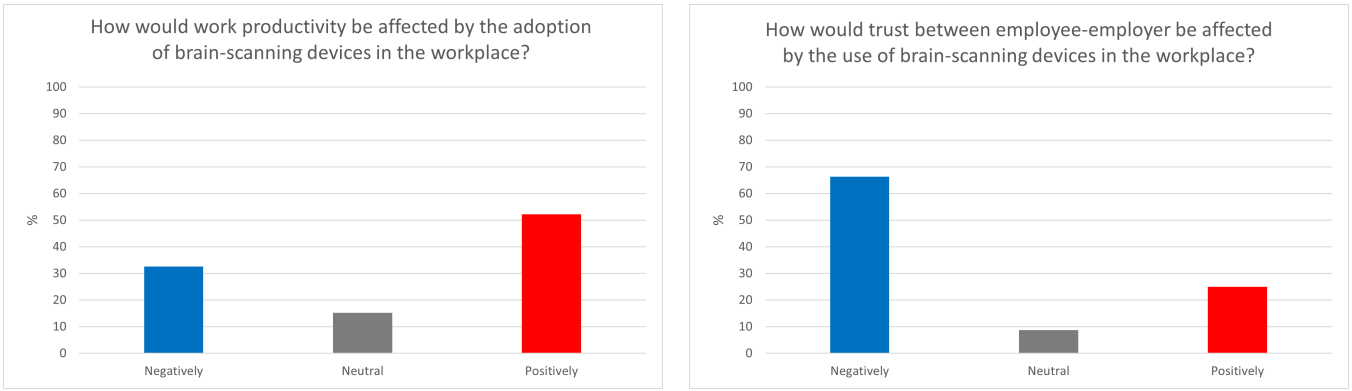
Respondents were asked to give their opinions on which professions would benefit from the use of brain-scanning technologies in the workplace. The professions stated were summarised in Table 2. In addition, the physical and mental demands of various vocations, as well as their impacts and repercussions on individuals and society, were included. For this we saw distinct groupings by the balance of both physical and mental workload, and whether the consequence of errors at work was more immediate or had a broader negative impact on others.

Participants were also asked to explain why those occupations would benefit from using neurotechnology. Table 3 summarises the findings, where we can see four major reasons. Two were for the benefit of companies, to prevent errors in safety critical work areas, to optimise or evaluate members of a workforce. This included safety critical covered normally in literature, like healthcare professionals and aviation workers (pilots and air traffic controllers). For the workforce, this included both as surveillance, but also for assessing people's capabilities for a task: *"Those are jobs that require a lot of focus and expertise, and these devices could help understand if a professional is capable of doing a certain job"* (P72). Indeed, assessments of capaibility are often found in safety critical work. Two further themes were for the benefit of individuals as a personal tool: to optimise effort for one's own achievements, and to help people's own stress and burnout. *"These professions go under a lot of trauma and stress due to the nature of their duties and honestly they don't have enough time to debrief, most of them rely on medication to stay sane because counselling is not effective, they are a ticking time bomb and suicidal so it will be good to detect the mental workload in order to assist them with necessary breaks"* (P 42).

4.1.3 Brain Data Concerns. To understand data privacy concerns, we asked participants about sharing their mental workload data with different groups: with family and friends, non-work related third parties such as insurance companies, with their employer to evaluate task difficulties, and to improve working conditions such as additional breaks or increase time off for overwhelmed workers. Figure 4 shows a summary of these views.

Most notably, 63% were uncomfortable in sharing their data with third parties, whereas only 26.08% of participants were uncomfortable in sharing their data with their employer to evaluate tasks difficulties, 26.1% were uncomfortable in sharing their data with family and friends and 17.4% were uncomfortable in sharing their data to improve work conditions. 64.1% of participants were *more* comfortable in sharing their data to improve working conditions, followed by 54.34% of participants that were comfortable in sharing their data to evaluate tasks difficulties, 48.9% of participants were comfortable in sharing their mental workload data with family and friends and only 13% of participants were comfortable in sharing their data with non-work related third parties. Friedman Test showed that participants' attitude in sharing their brain data was significantly different between the different scenarios, $\chi^2(3) = 79.454, p < .0005$. Post hoc pairwise comparisons with a Bonferroni correction, showed statistically significant differences in participants' attitude towards sharing brain data with non-work related third parties in comparison to each of the other conditions (each $p < 0.0005$).

Significant correlations were found between *sharing mental workload data* and some of the independent variables. *Willingness to share mental workload data with friends and family* positively correlated with *speed of technology adoption* with a p-value of 0.010 (laggards were less willing to share mental workload data for this purpose). Similarly, *willingness to share data with third parties* positively correlated with *technology adoption* with a p-value of 0.031 and negatively correlated with *age* with a p-value of 0.037 (older respondents were less willing to share mental workload data with third parties). *Attitude towards sharing mental workload data during specific work tasks* negatively correlated with *stress at work* with a p-value of 0.001, meaning that experiencing high stress at work



(a) The impact of mental workload tracking on work performance and productivity

(b) The impact of mental workload tracking on trust between employee-employer

Figure 3: Impact of mental workload tracking

Table 2: Professions reported by participants in the open-ended question:*"In your opinion, which professions should make mandatory the use of brain-scanning devices during working hours?"*

Professions	***Physical activity*** ***Mental workload*** ***Safety critical required in profession***	***Impact on individual and society***
Finance and accounting (Finance officers and accountants) Science (Researchers and Scientists) Education (Teachers) Legal (Lawyers and Judges) IT Corporate roles	Low physical activity High Mental workload	Long term impact on society
Aviation (Aircraft controllers and aircraft pilots) Healthcare (Doctors, Nurses, Psychologists and Psychiatrists) Transportation professions (Taxi drivers, Track drivers and Bus drivers)	Low/ Medium physical activity High Mental workload Safety critical	Long term impact on society Immediate impact on individual
Military (Soldiers) Law Enforcement and First Responders (Police officers)	Medium/High physical activity High Mental workload Safety critical	Immediate impact on individual

Table 3: Themes identified from the open-ended question:*"Could you please tell us why"?* (In reference to the question: *"In your opinion, which professions should make mandatory the use of brain-scanning devices during working hours?"*)

Themes	***Codes***
Safety Critical	Prevent human error To improve current safety measures
Workforce Management	To monitor workers performance Evaluate workers skills
Effort Management	Awareness of mental performance
Stress Management	Prevent burnout Improve wellbeing

was linked to being uncomfortable with sharing mental workload data for this purpose. Finally, *sharing mental workload data with the employer for the purpose of improving work conditions* negatively correlated with *age* with a p-value of 0.049 and *stress at work* with a p-value of 0.009. The correlation coefficients can be found in 11 and 12 of the appendix.

We also asked participants which types of cognitive personal data they would be most concerned in sharing with their employer. Surprisingly, in comparison to discussions in literature, the majority of participants (41.3%) were most concerned in sharing their mental workload data, followed by mood data (33.7%), and fewest of our participants chose stress level data (25%). These latter concerns are more related to mental health, and so perhaps the desire to improve mental health outweighs the concerns for our participants to share this data.

4.1.4 General Future Neurotechnology Concerns. Respondents were asked to express their feelings regarding future brain-scanning devices features (see Figure 5). It was found that 58.7% were excited and 15.2% were very excited in using a neurotracker to measure stress levels, while 6.5% were worried and 2.2% were very worried

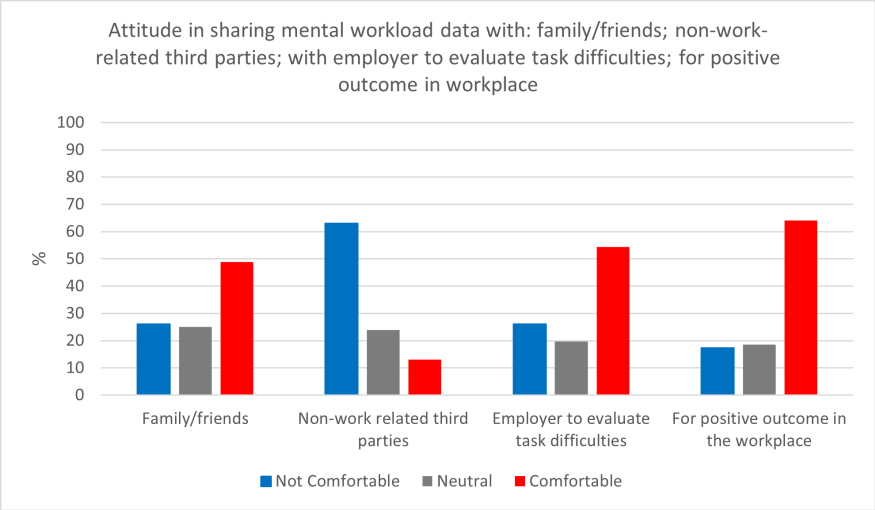


Figure 4: Participants' attitude towards sharing their brain data with family/friends; non-work related third parties; employer to evaluate tasks difficulties; to boost a positive workplace

about this feature. In regard to using a neurotracker to measure emotional states, 53.3% were excited and 16.3% were very excited, while 6.5% were worried and very worried. 44.6% of responders were excited and 41.3% were very excited in using a device that can help to improve their concentration, while only 3.3% were worried and 1.1% were very worried. Whilst in respect to a device that can help change emotional state, it was observed that 31.5% of participants were excited, 20.7% were very excited, while more participants, 17.4% were worried and 13% were very worried about this feature. These show two insights. First, as with the previous concerns about sharing, participants were excited about technology to manage stress. More in line with our expectations about mental workload, however, the strongest excitement was reported for improving concentration. Participants were more worried about technology that would change their emotional state, rather than simply monitor brain data.

We also found responders' *feelings towards the future of brain-scanning devices more specifically for measuring stress and emotions* negatively correlated with *age* (p-values of 0.021 and 0.031 for stress and emotions respectively) and positively correlated with *technology adoption* (p-values of 0.005 and 0.006 for stress and emotions respectively). Participants the most worried were older and slower at adopting technology. Correlation coefficients can be found in the appendix.

Participants were asked to report their main concerns regarding future brain-scanning devices. Themes and respective codes identified are reported in Table 4. Of these, *misuse for evil* was the most common theme. While this included the same negative associations as general surveillance, participants considered it could lead to new forms of exploitation. *"Brain-scanning devices could be abused as a way to discriminate against employees or abused in a manner that could result in higher workloads for employees"*(P 7). This could affect both hiring and firing, but ultimately participants felt concern over being judged: *"People with poor results will not be given the opportunity to prove otherwise"* (P 89).

Both *threat to physical health* and *device issues* were recurring themes of concern. While some had concerns over the safety of the devices, more participants were concerned on whether they were reliable, trustworthy, and whether it was realistic to base judgements or decisions on these forms of data. Indeed, the final theme on *concerns about use of data* was characterised by the fear that data might not be interpreted accurately or used effectively. Responder 109, for example, said *"All data can be manipulated and show any information in a bad light"* (P 109).

Table 4: Table showing key concerns, as clustered from open responses.

Themes	***Codes***
Misuse for evil in the workplace	Negative impact wellbeing Exploitation Negative impact hiring processes Getting fired Revelation of sensitive data Fear of being judge
Threat physical health	Brain damage
Device issues	Device malfunction Not reliable Lack of trust Inaccurate findings
Concerns about use of data	Manipulation Privacy breach To generate revenue

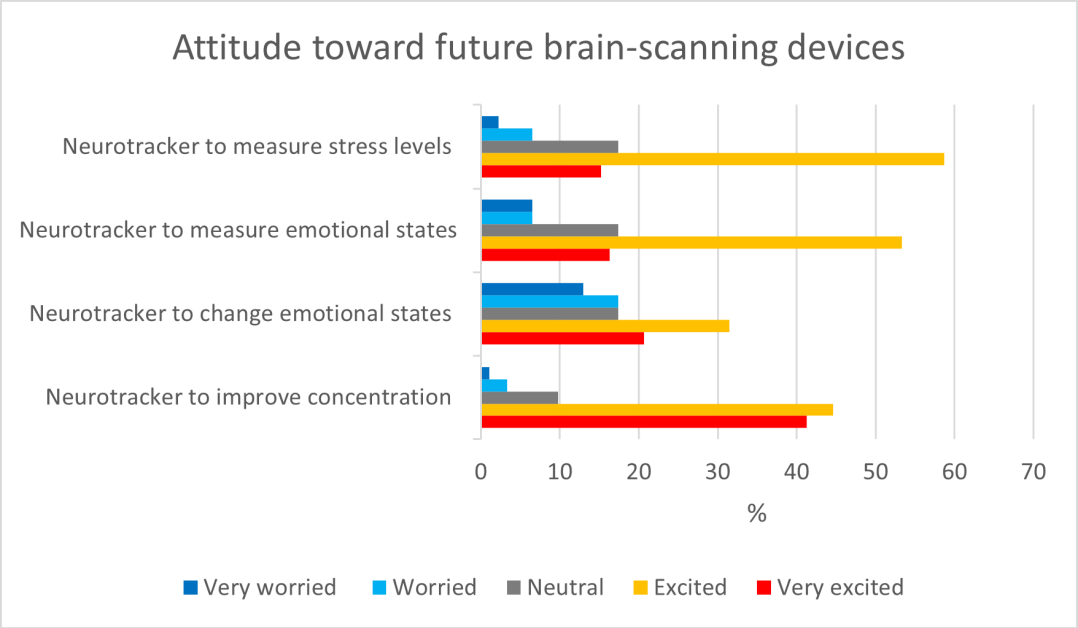


Figure 5: Participants' attitude about future features of brain-scanning devices

4.2 Interview Themes

Office and factory workers were interviewed in order to understand their view points in adopting brain-scanning devices in workplace settings. The resulting themes from these discussion are summarised in table 5.

Table 5: Thematic table map of interviews

Themes	***Subthemes***
Consequences	Biases and discriminations
	Decline workers' mental health and performance
	Challenge employee' rights
	Career impact
Trust and Agency	Relationship between employee-employer
	Brain data ownership
	Data use
Positive aspects	Reduce discrimination
	Improve employees' mental health

4.2.1 Consequences. Responders stated that this technology would have a negative impact if used in their workplace, as it could be just another way of being discriminated against. Participant 9 said it clearly: *"I think if anything it will probably lead to more discrimination and harm, it's just one of those situations where at the end of the day, if it's a human at the end of the technology that can see what's going on, it comes down to human error, and there's always going to be some form of prejudice in that persons decision to do with that data"*. Participants had concern about technology that might highlight neural activity that is not "normal". *"People who have mental health issues or are neurodiverse might be unfairly treated because their brain scans show events that suggests they're unenthusiastic"* (P2). Participants were concerned with essentially how data from the technology is interpreted. *"... even though they could say that they would be able to implement this technology without any bias whatsoever, that it is in my eyes impossible because the very nature of doing it and using it as even if they are gathering the data for the good of your health, they will use it for a reason so even if it's a positive bias is still a bias"*(P7).

Participants expected that these devices would decrease their wellbeing, by *causing anxiety and stress*: *"I just feel like it would affect someone mental health negatively, knowing that someone is constantly looking at how they are doing at work"*(P6). Furthermore, a quote also suggested that employers could base their expectation of the employees based on their mental state: *"If they see your emotions, they can expect that you do more when you are happy or maybe even like, not select you for some kind of prize like a daily price"* (P4), and the same participant also stated that using this device in the workplace could also cause penalties: *"If a manager saw when someone is upset or bored, they are not going to let this person leave earlier or it could lead me being dismissed from my work..."*. Participants also stated that the decline in mental health would impact work productivity: *"I don't think the quality of work will increase, I think because I will be too stressed for it to increase, so it would stay the same or it would get worse because I'm worried that they're watching everything that I do, and this will cause me to make more mistakes"* (P9).

Some participants were also worried that this technology would restrict employees' freedom and be used by employers to manipulate their workers: *"I'm concerned that this technology would restrict*

my freedom and my legal rights" (P8). Participant 6 said: *"I feel like employers could use that to manipulate you, by having that brain data, like having more power with that."* Another said: *"I would make sure that whatever technology that I'd be using that it doesn't restrict any of my freedoms... I would want to make sure it would be that 100% safe to us and I'm concerned that this technology would restrict my freedom and my legal rights in my job"* (P8). It is clear that questions about these legal positions were often at the centre, and while this is often at the forefront of surveillance concerns, it was exaggerated here by the highly personal nature of this data.

Finally, participants were worried about the longer effect this may have on their careers: *"... get fired from their job if something anomalous is detected in the brain scans"*(P2), and the repercussion in future job applications: *"If this starts impacting your personal life as well, not just, it will feel weird and also if that information gets shared with future employers it might affects you get hired in future companies"*(P3). Participant 6 made this more explicit, saying: *"Say that you wanted to change company in the future, but then the X company come back to you saying that they saw your brain scan, so they are going to reject your application".*

4.2.2 Trust and Agency. This theme identified employees' concerns related to trust of brain-scanning devices in the workplace, and whether it would affect the agency they had in their work. Several participants reported that these devices could be intrusive and break the employees' privacy rights. Participant 4 gave the most succinct view on this: *"On one side, I can agree that perhaps if we had a system like that, the company could evaluate if someone is happy or not in the company, which could actually, you know suggest that that person is going to be a loyal worker because obviously they always productive if they're always happy, then you know they are likely to stay in that job for longer. So that would probably increase the trust between employees and the company. On the other hand, though, so the trust between employees and company. I think in my personal opinion might actually decrease because if they putting that employee makes them feel like they're not doing enough at work. Uh, if they are using that kind of system to measure productivity is just, for example, I have a monitoring system in my office right now and they measure every single task that we do per minutes, so they actually measure every single thing that we do. And if we're like inactive for two minutes, they will message us and it doesn't matter if you've done 100 emails and calls, if you are not active for those two minutes, then you know you're likely that they will tell you off basically. So, I think if a system like this actually measures your productivity all the time at work, that would make you know employees less loyal to the company because they would not want to work in a company like that..."* (P4).

An interviewee has reported that if an employer introduced these devices in the workplace, this would be a sign of disrespect and distrust toward their workers: *"If I employ you, I should respect you enough to know you're always do the best you can at the job. Brain monitoring seems like disrespectful and distrustful (P2)","... trust decrease because if they putting that, employees makes them feel like they're not doing enough at work"* (P4).

Interviewees were also concerned about ownership of brain data: *"I'm worried about or who has control over the legal concerns, because even if they have control over it if there's no laws to protect basically the public and the peoples whose information is being taken, then it doesn't really matter who has control over it"* (P5).

It was also found that many quotes were related to the employer's honesty in the use of brain data and transparency about the data collected: *"... so, if you tell them you're only going to monitor one thing and then you monitor something else, which is quite private in their eyes, then you lose that trust and they'll just not use it or refuse"* (P3). It was also suggested that trust could be potentially impacted by the powerless feeling that employees have over how their brain data is being used: *"How do you know if they are actually collecting that data, or if they're collecting something else? Because you have no real control over what they're collecting, you just taking their word for it"*(P3).

4.2.3 Positive Aspects. Some participants also reported more positive implications from involving neurotechnology in the workplace. In particular, it was pointed out that brain-scanning devices may reduce discrimination on irrelevant factors such as employees' appearance or race: *"In a way it can help to diminish racism or nationalism in factories. Because sometimes there is a lot of racism there, and these devices can tell who is good or not good without be biased by race of worker"* (P1). Another quote said: *"... in a way I believe it could definitely protect employees from discrimination. The reason is because obviously right now, you know it's a global problem, but it's for between woman and people from minorities like it's the appearance that has a little bit of effect on discrimination and disabilities. Obviously with this it would allow employers to actually see each individual person and actually based the on their merits of their work rather than their appearance..."* (P4). It was also suggested the positive improvement of this technology on employees' mental health: *"... if it is able to analyse fatigue in employees, the employer can realise if they are overworked"* (P5); and on their work performance: *"I will feel more productive because they are checking me in public. So, for example, if they see that I am slacking off, they can see it on my brain data. So, I would want probably to do more so my brain looks more active"* (P9). These results are in line with the findings from the questionnaire relating to the willingness to share data about stress, and the excitement about technology that might be able to track stress.

5 DISCUSSIONS

This investigation focused on giving employees' voice about their concerns related to the use of brain-scanning devices in the workplace, as well as their attitude and perception about adopting these devices in their personal lives.

5.1 Adoption of Brain-scanning Devices Outside the Workplace

Overall, respondents had a positive attitude toward using a brain-scanning technology in their daily life. According to the results of the survey, respondents seemed interested in adopting brain-scanning technologies to measure their own mental workload, in order to track their stress levels, and monitor their brain health. Furthermore, the majority of survey respondents believe that this technology can improve their work-life balance, productivity, and mental health. Similar findings were obtained in a previous study

where attitudes toward computerised cognitive training were investigated [25]. Furthermore, research has reported that self-awareness of own mental workload and cognitive state was beneficial and have positive impact on people lives [43, 48]. Moreover, more than half of participants felt that tracking mental workload is just as important as tracking physical activity for monitoring and improving health, in particular in the open-ended question, participants viewed tracking mental workload as just as important for brain health, as tracking physical activity for physical health. Indeed instead of highlighting differences, participants highlighted the interdepence between them. These findings are noteworthy because an increasing number of fitness wearables and apps are implementing cognitive monitoring as well as physical activity tracking. Indeed, research is starting to examine the design for personal cognitive informatics in line with the differences between mental and physical tracking that our participants reported [74].

5.2 Adoption of Brain-scanning Devices in the Workplace

The survey findings reported that participants have a negative attitude in using neurotechnology to monitor they mental workload during working hours, indeed more than half of respondents stated that they would have uncomfortable feelings about it. Perhaps not unexpectedly, similar results were obtained if this technology was used during hiring processes. However, the correlation tests also showed that participants who have low familiarity with neurotechnology, as well as employees who stated to have high stress levels in the workplace, were particularly linked with being uncomfortable in using this technology during working hours and in recruitment contexts.

When participants were asked if they were willing to let their employer to track their mental workload, 44.6% of respondents would not allow it; however it is interesting to observe that 34.8 % were uncertain, suggesting that these participants may see a positive benefit in this technology but are also concerned about the negative aspects. Furthermore, the same amount of participants (20.7%) who said they were comfortable with their company tracking their mental workload were also willing to let their employer track their brain data.

In regards to how neurotechnology in the workplace influences productivity, more than half of participants reported that it would have a positive improvement. Similar findings were seen in previous studies [56, 66] in which it was observed that high surveillance systems increase productivity on a task, however the quality of the work decreased. This could suggest that continually monitoring employees (e.g. when using a brain-scanning device) might causes a change in their behaviour in order to be seen as productive [39].

However, according to Martin and Freeman [42], constant monitoring has a negative impact on work productivity because it causes constant stress for the employees, and this in turn could increase the likelihood of them becoming unwell and taking sick leave. Additionally, it was also suggested that monitoring systems that threaten workers' privacy could also be responsible in negatively influencing employees' physical and mental health. Our findings could suggest that monitoring employees using a brain-scanning device might, according to respondents' answers, boost their work productivity since they are known to be monitored, but this could be at expense of their mental health and in the long run it could be counterproductive for the organisation.

Furthermore, correlation tests have identified that older participants, participants that are in high stress occupations, and laggards (in terms of technology adoption) believe that this technology would have a negative impact in the workplace. In terms of how this technology might affect the employee-employer trust relationship, the majority of respondents feel that it will have a negative influence, and this was linked to participants who are more stressed at work, as well as laggards, according to correlation analysis. These findings were largely consistent with previous research, which found that high surveillance approaches, such as neurotracking, as well as health tracking are seen negatively in the workplace [1, 9, 11, 50]. The positive aspects identified suggests that employees might perceive the implementation of neurotechnology devices as a sign that the company care about their wellbeing, also observed in other studies[14].

5.3 People's Concerns about their Mental Workload Data

The majority of people were mostly concerned about sharing their mental workload data with non-work-related third parties (e.g. insurance companies). Conversely, and perhaps more so than one would expect from discussion in literature, participants felt more at ease sharing their mental workload data with family and friends, and especially with their company in order to assess how tough a work task is and to improve working conditions. Indeed, in comparison to the previous questions, where participants were asked if they would allow their company to track their mental workload, a higher percentage of participants are willing to share their brain data with their employer for analysing task difficulties and for positive outcomes.

Furthermore, it was observed that there is a positive correlation between the speed with which people adopt technology and their willingness to share mental workload data with friends and family, as well as non-work-related third parties, implying that early adopters are more willing to share their data than laggards. The willingness to share their mental workload data with non-work-related third parties was also found to be inversely linked with age, suggesting that older participants were less keen to share their data with third parties organisations. It seems clear that familiarity with technology, and most likely wearable technology and personal informatics, makes the potential use of neurotechnology in the workplace more acceptable to participants.

Similarly, a negative correlation was noticed between participants' workplace stress levels and their willingness to share their brain data with their employer to evaluate task difficulties and for positive work improvements, implying that higher-stress professions may be less likely to share their brain data for those purposes. The willingness to share data for a positive outcome in the workplace was negatively connected with age, suggesting that older employees are less likely to believe that this technology is beneficial in the workplace.

Participants were also asked to state which kind of brain data they are more concerned in sharing. According to the survey, respondents were more concerned about sharing their mental workload data compared to mood and stress levels data. These findings are noteworthy since knowledge about someone's mental workload can suggest their level of engagement while executing a task, whereas mood and stress levels data can be more intrusive because it can reveal more hidden information about someone's mental health [63]. However, it's worth noting that these findings could be biased due to the survey's focus on mental workload data.

5.4 Attitudes and Concerns Towards Future Brain-scanning Devices

Respondents had a positive outlook toward future features in brain-scanning devices; in particular, neurotrackers that can improve concentration were identified as the most exciting, followed by devices that can measure stress levels, emotional states, and finally devices that can help change emotional states. The latter was found to be the source of the most concern among participants. This could be related to the fact that a technology capable of altering an individual's behaviour raises concerns about sense of agency (e.g. who is performing this action or why am I feeling depresses, is this the result of using the neurotracker or is it myself?). A growing body of research are raising concerns about neurotechnology's ability to alter mental states both in clinical and non-clinical applications [16, 23, 24, 29].

Findings from the open-ended question revealed that participants had similar worries about future brain-scanning devices as those seen when the neurotechnology is applied in the in workplace, for this reason it was decided to dedicate the theme "misuse for evil in the workplace". Moreover, respondents were concerned about physical health issues that prolonged use of this technology could cause (e.g., brain damage), as well as issues with the technology and the inaccuracy and unreliability of the data collected. Concerns about use of brain data remained one of the challenges, as previously found in this study.

5.5 Limitations and Future Work

The majority of survey respondents and interviewees were between the ages of 18 and 45, with an underrepresentation of senior people. This could be due to two factors: older people may be less likely to use Prolific, or they could be retired (since we required people in full time work). Another limitation of this study was that most of the employees interviewed performed similar duties in what are sometimes called white-collar office jobs, all the interviewees had at least a Bachelor's degree, and were in the same age range (between 20-30 years old). Furthermore, it is important to take in to consideration that the demographics of the interviewees (mostly from Western cultures) might have played an important role in determining the attitude towards the use of neurotechnology in the workplace. Different cultures may have different views in regards to their working environment and their ethics. Further studies should take these limitations into consideration and consider opinions from a wider and more diverse population.

Additionally, it was observed that some participants struggled to understand the concept of mental workload, and that it was frequently mistaken with stress. However, because there is a lack of a unified explanatory framework for mental workload, it may be difficult for the general public to grasp this concept. Mental workload, like stress and fatigue, are transactional concepts that combine inter-individual sources of trait variability, such as IQ, individual personality, and skills, with intra-individual variation, such as fatigue, motivation, and emotional states [17]. For this reason, despite our efforts to ground the survey and interview, participants could have had difficulties in understanding this concept. Furthermore, despite having informed the participants about the limitations and capabilities of this technology, some participants still had an inaccurate and overoptimistic picture of the current state of neurotechnology devices.

For future work, we expect that participants will soon have more direct access to consumer neurotechnology. With examples being available to users from as little as $200, future work can begin to study people's lived experience with neurotechnology both in life and at work.

6 CONCLUSIONS

This study investigated people's attitudes toward the adoption of brain-scanning device in daily life, employees' attitudes and concerns in the use of neurotechnology in their workplace, the professions that could benefit in using this technology, people' s concerns about their mental workload data, and people's attitude and concerns toward future neurotechnology devices. Findings suggested that people have a positive attitude toward neurotechnology to track their own mental workload, but when this technology is deployed into the workplace there is an overall negative perception. However, in certain professions that have high mental workload and in safety critical occupations it could be beneficial. Participants were mostly concerned in sharing their data with third-parties, but perhaps surprisingly more comfortable in sharing their data with their employer for a positive workplace. Furthermore, respondents expressed enthusiasm for future brain-scanning technologies, particularly those that can boost concentration and track their stress. Finally, these results emphasise the need for taking into account people's concerns before and while using consumer neurotechnology devices for cognitive health purposes, as well as in the workplace. In particular, before deploying this technology in people's daily lives, it is critical to establish guidelines on who owns the cognitive data obtained by these devices and how are these data processed.

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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: questionnaire data and anonymised transcripts of interviews.

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A ADDITIONAL STUDY INFORMATION

These appendices include the full detail of the questionnaire (in Tables 6-9) and information about the Moral IT Cards (Table 10) used as prompts in the interviews. This is followed by detailed correlations from the quantitative analysis of the questionnaire (Table 11 and Table 12).

Table 6: Questions and possible answers of the questionnaire: part 1

Questions	**Answer options**
What is your gender?	Male / Female / Non-binary / Prefer not to say
What is your age?	18-25 / 26-45 / 46-60 / 60+
What is your occupation?	Open-ended question
Which of the following best describes your current job level?	Entry-level - Junior / Intermediate / Experienced / Advance / Senior
How physical is your job?	Not at all physical / Somewhat physical / Moderately physical / Very physical / Completely physical
How much stress is in your life? How much stress is in your job?	Not at all / Very mild / Mild / Moderate / Extreme
How much mental workload is involved in your daily life duties?	Not at all / Very mild / Mild / Moderate / Extreme
How much mental workload is involved in your job?	Not at all / Very mild / Mild / Moderate / Extreme
In respects to new technologies, do you consider yourself as part of:	- Early Adopters (first people to embrace a new technology before general population) - Early Majority (people that take their time to adopt a new technology, but willing to embrace it as long as it fits in their lives) - Late Majority (people that adopt a new technology in reaction to peer pressure, or emerging norms. Sceptical about new innovations) - Laggards (last people to adopt a new technology)
How familiar are you with Neurotechnologies?	Not at all familiar /Somewhat familiar / Very familiar / Extremely familiar
Please answer the following question about your understanding of this survey: - This survey is about devices that can detect what an individual is thinking in real time. - This survey is about devices that can detect the amount of mental resources involved to perform a task. - This survey is about devices that can monitor mental health conditions such as depression. ##Comprhension check	Yes / No

Table 7: Questions and possible answers of the questionnaire: part 2

Questions	Answer options
Imagine you could use a device that tracks the amount of mental resources required by your brain to do a task. Would you be interested in using this device in your daily life?	Not interested at all / Somewhat interested / Neutral / Interested /Very interested
For which purposes would you be interested in adopting a brain-scanning device?	Improve brain performance / Monitor personal wellbeing (eg. reduce stress) / Monitor mental health / Improve work performance / Other / None
- Tracking my mental workload would help me to improve work-life balance - Tracking my mental workload would help me to be more productive with my daily duties - Tracking my mental workload would help me to improve my mental wellbeing	Strongly Disagree / Disagree / Somewhat Disagree / Neutral / Somewhat agree / Agree / Strongly agree
Do you track your daily physical activity with fitness tracking devices such as Fitbit or Apple watch?	Yes / No / Sometimes
How much do you agree or disagree with this statement: "Tracking my mental workload is like tracking my physical activity."	Strongly Disagree / Disagree / Somewhat Disagree / Neutral / Somewhat agree / Agree / Strongly agree
In your opinion, what are the differences between tracking mental workload compared to tracking physical activity?	Open-ended question

Table 8: Questions and possible answers of the questionnaire: part 3

Questions	Answer options
- Imagine that you are applying for a new job in a company, and during the recruitment process, you are asked to wear a brain-scanning device while executing similar tasks like the role you have applied for. How would you feel? - Imagine that in your current job your employer asks you to wear a hat which contains brain sensors to monitor how much mental effort you are using while being engaged in a work task. How would you feel?	Very Uncomfortable / Uncomfortable / Neutral / Comfortable / Very Comfortable
Please state your feeling about these scenarios: - How do you think your performance/productivity will be impacted by the adoption of brain-scanning devices in the workplace? - How could trust between employee-employer be affected by the implementation of brain-scanning devices within the workplace?	Strongly Negatively / Negatively / Somewhat Negatively / Neutral / Somewhat Positively / Positively / Strongly Positively
Would you allow your employer to monitor your mental workload while at work?	Yes / No / Maybe
In your opinion, which professions should make mandatory the use of brain-scanning devices during working hours? Could you please tell us why?	Open-ended questions

Table 9: Questions and possible answers of the questionnaire: part 4

Questions	Answer options
Please state your feelings in relation to the mental workload data collected by brain-scanning devices. - How would you feel about sharing your mental workload data with family or friends? - How would you feel about sharing your mental workload data with non work-related third parties, such as insurance companies? - How would you feel about sharing your mental workload data during occasional specific tasks, so your employer can evaluate how hard the task is? - How would you feel about sharing your mental workload data with your employer to decrease employees' stress levels, improve working conditions such as increase breaks, or increase time off for overworked employees?	Very Uncomfortable / Uncomfortable / Neutral / Comfortable / Very Comfortable
Please state your feelings in relation to future Neurotechnology devices: - How would you feel about a future brain-scanning device that could measure your stress levels? - How would you feel about a future brain-scanning device that could measure your emotional state, such as sadness, happiness, and anger? - How would you feel about a brain-scanning device that could help you to improve your concentration? - How would you feel about a brain-scanning device that could help you change your emotional state? - Which brain data would you feel more concerned in sharing with your employer?	Very Worried / Worried / Neutral / Excited / Very Excited
What do you think could go wrong in future brain-scanning devices?	Open-ended question

Table 10: This table contains the questions linked to the Moral IT Cards [15].

Framework	Question
Privacy	Who is responsible for the brain data collected? Do you think this type of technology may violates the privacy rights? What are your legal concerns related to privacy? Control over personal brain data collected
Ethics	Do you think the adoption of this technology in the workplace could lead to bias/ prejudice? Trust between employees-company What are the consequences of this technology for the freedom of employees? What would be the consequences of this technology for the wellbeing of the employees?
Law	Do you think this technology would create harmful effects within the workplace or improve it? Which precautions should employers take while adopting this technology in the workplace? Do you think this technology could provide caring for employees? Do you think this technology could protect the employees from harm or discrimination?
Security	Who should be allowed to see your brain data? Integrity and honesty of the use of this technology in the workplace How does confidentiality features in this technology? Do you think this technology could threaten people 's identities?

Table 11: Analysis of correlations with Spearman's rank tests. Values of *rho* with an asterisk represent significant correlation at a 5 % error threshold.

rho (Spearman's rank test)	age	familiarity_neurotech	tech_adoption
mwltrack_help_work_life_balance	-0.08568554	0.0577877	0.1401285
mwltrack_help_more_productive_daily_duties	-0.02583033	0.04314708	0.185054
mwltrack_help_improve_wellbeing	-0.06197901	-0.09759607	-0.007150506
brainscan_recruitment	-0.1659368	0.2109344 *	0.3055881 *
mwltrack_work	-0.1967171	0.2277282 *	0.2578142 *
share_mwl_friends_family	-0.168918	-0.05361208	0.2701849 *
share_mwl_third_parties	-0.2174675 *	0.1186232	0.2255645 *
share_mwl_specific_work_tasks	-0.1871108	0.1139527	0.1639568
share_mwl_employer_better_conditions	-0.2058748 *	0.08015564	0.1982179
brainscan_impact_performance_productivity	-0.2445968 *	0.07500103	0.2709096 *
brainscan_impact_trust	-0.1938398	0.161408	0.3530609 *
future_brainscan_stress	-0.2409266 *	0.1350282	0.2877185 *
future_brainscan_emotions	-0.2254565 *	0.09697735	0.2825685 *
future_brainscan_concentration	-0.04316056	-0.003917104	0.185977
future_brainscan_change_emotions	-0.01847784	0.1598088	0.1871357

Table 12: Analysis of correlations with Spearman's rank tests. Values of *rho* with an asterisk represent significant correlation at a 5 % error threshold.

rho (Spearman's rank test)	stress_life	mwl_life	stress_job	mwl_job
mwltrack_help_work_life_balance	0.1767083	0.04680279	0.004458024	0.08294824
mwltrack_help_more_productive_daily_duties	0.1039193	-0.0533711	-	-
mwltrack_help_improve_wellbeing	0.1088874	0.1050723	-0.0403987	0.02997725
brainscan_recruitment	-	-	-0.2927984 *	-0.1921188
mwltrack_work	-	-	-0.245561 *	-0.09699036
share_mwl_friends_family	-0.05893911	-0.03493619	-	-
share_mwl_third_parties	-0.05969073	-0.1261376	-	-
share_mwl_specific_work_tasks	-	-	-0.3425003 *	-0.02960742
share_mwl_employer_better_conditions	-	-	-0.2703425 *	-0.06126826
brainscan_impact_performance_productivity	-	-	-0.3098255 *	-0.1942029
brainscan_impact_trust	-	-	-0.3245391 *	-0.199097