Investigating the effects of neurofeedback on knowledge workers' perceptions of self-accomplishment, focus and task performance

Mitrevska, Teodora; Kobiella, Charlotte; Feckl, Julia; Sakel, Sophia; Butz, Andreas Martin; Schneegass, Christina

DOI
10.1145/3764687.3764696

Licence
CC BY

Publication date
2025

Document Version
Final published version

Published in
OZCHI 2025 - Proceedings of the 37th Australian Conference on Human-Computer Interaction

Citation (APA)
Mitrevska, T., Kobiella, C., Feckl, J., Sakel, S., Butz, A. M., & Schneegass, C. (2025). Investigating the effects of neurofeedback on knowledge workers' perceptions of self-accomplishment, focus and task performance. In J. Fredericks, S. Yoo, T. T. Minh Tran, N. Pantidi, T. Hoang, M. Hoggenmueller, G. Caldwell, B. Tag, J. Andres, & More Editors (Eds.), *OZCHI 2025 - Proceedings of the 37th Australian Conference on Human-Computer Interaction* (pp. 343-355). ACM. https://doi.org/10.1145/3764687.3764696

RESEARCH-ARTICLE

Investigating the effects of neurofeedback on knowledge workers' perceptions of self-accomplishment, focus and task performance

TEODORA MITREVSKA, Ludwig-Maximilians-University Munich, Munich, Bayern, Germany

CHARLOTTE KOBIELLA, Center for Digital Technology and Management, Munich, Bayern, Germany

JULIA FECKL, Ludwig-Maximilians-University Munich, Munich, Bayern, Germany

SOPHIA SAKEL, Ludwig-Maximilians-University Munich, Munich, Bayern, Germany

ANDREAS MARTIN BUTZ, Ludwig-Maximilians-University Munich, Munich, Bayern, Germany

CHRISTINA SCHNEEGASS, Delft University of Technology, Delft, Zuid-Holland, Netherlands

Open Access Support provided by:

Ludwig-Maximilians-University Munich

Delft University of Technology

Center for Digital Technology and Management

Published: 29 November 2025

Citation in BibTeX format

OZCHI '25: 37th Australian Conference on Human-Computer Interaction
November 29 - December 3, 2025
Gadigal | Sydney, Australia

OZCHI '25: Proceedings of the 37th Australian Conference on Human-Computer Interaction (November 2025)
https://doi.org/10.1145/3764687.3764696
ISBN: 9798400720161

Investigating the effects of neurofeedback on knowledge workers' perceptions of self-accomplishment, focus and task performance

Teodora Mitrevska
LMU Munich
Munich, Germany
teodora.mitrevska@ifi.lmu.de

Charlotte Kobiella*
Center for Digital Technology and Management
Munich, Germany
kobiella@cdtm.de

Julia Feckl
LMU Munich
Munich, Germany
julia.feckl@campus.lmu.de

Sophia Sakel
LMU Munich
Munich, Germany
sophia.sakel@ifi.lmu.de

Andreas Martin Butz
LMU Munich
Munich, Germany
butz@ifi.lmu.de

Christina Schneegass
Delft University of Technology
Delft, Netherlands
c.schneegass@tudelft.nl

Abstract

Knowledge workers often struggle to evaluate their productivity and sense of accomplishment due to the intangible nature of their work. They rely on internal cues and personal metrics such as focus, effort, or goal completion. Traditional productivity tools overlook these dimensions, creating a gap between effort and perceived performance. This study examines how neurofeedback influences perceptions of self-accomplishment, focus, and task performance. We conducted a study in which *N=20* participants completed reading and writing tasks while wearing a commercial EEG headband. Each participant completed one task with live neurofeedback and another with feedback shown afterward. While neurofeedback did not change how participants defined self-accomplishment, it encouraged reflection and awareness of cognitive effort. Some found the feedback validating, while others felt pressure or questioned its accuracy. Our findings suggest that neurofeedback can aid self-reflection in knowledge work when it is unobtrusive, ensures data comprehensibility, and supports users' existing self-evaluation strategies.

CCS Concepts

• **Human-centered computing** → *Human computer interaction (HCI).*

Keywords

neurofeedback, self-accomplishment, knowledge work, cognition, personal informatics

*Also with LMU Munich.

OZCHI '25, Sydney, Australia

ACM ISBN 979-8-4007-2016-1/25/11
https://doi.org/10.1145/3764687.3764696

ACM Reference Format:
Teodora Mitrevska, Charlotte Kobiella, Julia Feckl, Sophia Sakel, Andreas Martin Butz, and Christina Schneegass. 2025. Investigating the effects of neurofeedback on knowledge workers' perceptions of self-accomplishment, focus and task performance. In *37th Australian Conference on Human-Computer Interaction (HCI) (OZCHI '25), November 29–December 03, 2025, Sydney, Australia.* ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3764687.3764696

1 INTRODUCTION

As traditional productivity metrics continue to emphasize quantity over quality, knowledge workers might find it challenging to measure their accomplishments when their work is often difficult to quantify and produce immediate outcomes. Compared to manual workers, whose outputs come in tangible form and whose contributions are measured in hours of labor, knowledge work often involves critical thinking, problem-solving, planning, analyzing, and decision-making - all tasks that are difficult to materialize [13, 15, 27]. Thus, due to the complex and intangible nature of knowledge work, it is difficult to measure productivity in conventional metrics [13, 16]. In response, many knowledge workers develop personal metrics (e.g., quality of output, attention, emotional satisfaction), making the definition of productivity subjective and multidimensional [30, 47].

These self-defined strategies help knowledge workers measure their progress and develop a sense of moving forward in work that often lacks clear endpoints. Among these internal strategies, the *feeling of self-accomplishment* stands out as an indicator that the effort invested in a task was worthwhile [41, 42]. Unlike traditional metrics that often emphasize the number of hours invested in the work, self-accomplishment offers an intrinsic sense of satisfaction that can help people to sustain motivation in cognitively demanding roles [5, 57] and feel confident in their ability to handle more challenging tasks in the future [31, 32]. While self-accomplishment plays an important role in sustaining motivation, it is mostly shaped by internal impressions or influenced by the judgment of others - which can be misaligned with the actual effort. Conventional productivity tools - such as time trackers, performance dashboards, task lists, etc. fail to capture the cognitive dimension that drives self-accomplishment. Cognitive dimensions such as focus and mental effort are crucial for the knowledge worker's performance [18, 23, 25, 46] - yet they remain underexplored and difficult to measure. While these dimensions might not be applicable as quantifiers of output, they offer a unique opportunity for situational self-reflection on cognitive effort. This raises the question: *What if knowledge workers could quantify their internal cognitive state such as their level of focus, to gain insights into their productivity during daily tasks?* Novel neurofeedback systems [1–3, 9], which provide real-time information derived from brain activity, offer users insights into their mental states. In the past, these systems have been explored in controlled clinical or therapeutic settings - such as treating Attention Deficit-Hyperactivity Disorder (ADHD) or anxiety, and training sustained attention [6, 8, 56] - but their role in supporting reflection of everyday work performance is unknown. Specifically, very little is known about how neurofeedback might influence the way knowledge workers perceive their own focus and manage cognitive efforts. Unlike clinical applications, where neurofeedback is often goal-directed and tightly controlled, knowledge work presents a more fluid environment where internal feedback could shape momentary behavior but also long-term perceptions of cognitive effort. To investigate the effects of neurofeedback at the workplace, we pose the following research question:

> **RQ:** How does real-time neurofeedback on focus levels influence knowledge workers' perceptions of self-accomplishment and task performance?

To answer this question, we conducted a study with knowledge workers (N=20) completing two common work tasks - a reading and a writing task in a counterbalanced order. During the task completion periods, we recorded EEG signal via a wearable EEG device FocusCalm [1]. The data was interpreted in metrics such as focus scores and visualized in the device-corresponding UI, which we presented to the participants, after the first task and during the second task. The participants reflected on their definitions of self-accomplishment, task difficulty and performance, and the recorded data. Our results show that real-time neurofeedback did not alter the knowledge worker's pre-existing definitions of self-accomplishment, which were primarily based on goal completion and output quality. However, it did prompt reflective awareness of their cognitive effort, which shows the potential of neurofeedback as a tool for gaining insights into mental effort. While some participants found the scores aligned with their perceptions, others were skeptical about the accuracy of the measurements, revealing subjective variability in the interpretation of the results. Moreover, displaying the scores during the task performance introduced pressure in the participants, indicating that neurofeedback may be more effective as a reflective tool, rather than as a live performance guide.

2 RELATED WORK

2.1 Self-accomplishment in the Workplace

Personal accomplishment plays a central role in how individuals experience and evaluate their work. It is commonly described as the feeling of competence and successful achievement in one's professional activities, especially in roles involving interaction with others [41, 42]. In the workplace, this sense of accomplishment reinforces motivation, encourages persistence, and enhances the perceived value of one's contributions. Particularly in creative or cognitively demanding roles, personal accomplishment is linked to confidence in problem-solving and innovation. A history of successfully navigating work challenges supports the belief that one can handle future, possibly more complex, tasks [26, 57]. This connection between task mastery and confidence suggests that accomplishment is not only a reflection of past success but also a predictor of future creative engagement [19].

Research further suggests that when individuals feel they are making meaningful progress, their productivity, creativity, and motivation tend to increase [29, 54]. These outcomes feed back into a positive cycle of performance and internal validation, reinforcing the significance of personal accomplishment in sustaining high-quality work over time.

Beyond measurable outputs, the sense of accomplishment also contributes to the subjective quality of the work experience. It supports long-term engagement and resilience, offering an intrinsic reward that can be more meaningful than external metrics for productivity alone [5, 64]. For example, in learning contexts, appropriately challenging tasks, such as those supported by AI tools, have been shown to enhance users' sense of accomplishment, highlighting the importance of balance between difficulty and skill [45]. Recent work has extended this idea to generative AI tools in knowledge work: Kobiella et al. [31] found that while some users experienced a diminished sense of ownership or challenge, others felt enhanced accomplishment when they used large language models (LLMs) like ChatGPT strategically, particularly when they retained control through post-processing or developed prompting strategies that reflected their own creative input. In follow-up work, Kobiella et al. [32] observed that prolonged LLM use led to higher ratings of perceived accomplishment, suggesting that adaptive integration of such tools may, over time, enrich subjective work fulfillment. These findings suggest that external tools can enhance performance in ways that positively affect subjective experiences like self-accomplishment. This raises a further question: can the evaluation of one's mental state, through technologies such as brain activity -tracking, also shape how accomplished individuals feel, even without directly improving task outcomes? Additionally, while these psychological factors have traditionally been studied through self-report and behavioral metrics [31, 32, 45], emerging technologies such as brain activity - tracking provide new avenues for capturing real-time indicators of cognitive engagement and accomplishment.

2.2 (Cognitive) Personal informatics as Self-Reflection Tool

Personal Informatics (PI) systems became prevalent with the introduction of fitness tracking wearables in the early 2010s [20, 49], with Fitbit being one of the most prominent examples. Through wristband or chest straps, users could collect data on their heart rate, step count, daily active time, and many other metrics. The aggregated and processed data can help users self-monitor and self-reflect [20] on their health, fitness, and daily activity. The use of PI devices can be motivated by a specific goal, such as weight loss or planning to run a marathon, but can also originate from mere curiosity for numbers [20, 49]. Beyond fitness trackers, PI systems can be used to quantify other activities, e.g., eating/food, financial transactions, locations, and mental health.

Recently, research has started examining cognitive personal informatics (CPI) as an emerging subdomain of PI [52, 61, 62]. CPI focuses on collecting data on cognitive processes such as focus, stress, or attention in contrast to physical activity. The aim is to enable individuals to reflect more deeply on their cognitive processing and, in the long term, improve their well-being and make more informed decisions [52]. While the technology is still in its infancy, cognitive tracking technologies (CCTs) are already available to consumers. Products like Muse, Neurocity, and FocusCalm utilize a variety of physiological signals, e.g., electroencephalography (EEG), functional near-infrared spectroscopy (fNIRS), and breathing rate, to infer cognitive states. Although research on the consumers' perspective on CPI is scarce, the technology has proven to deliver insightful data in research contexts [50].

2.3 Bio- and Neurofeedback

Biofeedback technologies, similar to CPI systems in general, are gaining increasing popularity in mainstream HCI research, as well as in consumers' everyday lives. Biofeedback systems aim to support users in gaining insights into their physiological processes, enhancing their self-regulation, and potentially improving their control over body and mind [53]. Lux et al. [37] present a comprehensive overview of opportunities and challenges when deploying biofeedback technologies in people's everyday lives, emphasizing the importance of data interpretability, relevance to personal goals, and easy access. Specifically focusing on Neurofeedback [60], research has explored EEG and fNIRS for real-time reflection on cognitive processes. Recent studies show that fNIRS, although still tentatively, holds promise in supporting users to regulate their hemodynamic signals – in other words, users had some success in modulating attention and cognitive control. fNIRS is particularly promising for HCI research contexts and everyday applications, due to its comparably low cost, tolerance for motion, and portability [10, 33, 53].

3 METHODOLOGY

3.1 Procedure

Upon arrival, after being informed about the purpose of the study, the procedure, their rights and data confidentiality, participants signed an informed consent form. They were also given a short description of the apparatus and a demonstration on how it works before they proceeded with their tasks and the survey. The participants were told that they need to complete two tasks, during which we will measure their brain activity with the FocusCalm[1]. To further ensure ecological validity, the participants were presented with tasks that they would usually execute on a daily basis, i.e a reading and a writing task [35]. The writing task encompassed producing a description of their favorite project completed so far, and the reading task encompassed reading a workshop proposal. To ensure that the participants thoroughly read the proposal, they were told they have to provide a short description of what they read. During the task completion periods, they were left alone in the room in order to minimize distractions or noise. After finishing the first task, we asked the participants to observe and interpret the visualization of the recorded data in the FocusCalm application. Before starting with the second task, they completed a post-task survey to reflect on their experience with the first task. The same sequence was completed for the second task, except that here, the participants were able to see the live recording of the brain data in the application at any time. To monitor any potential effects related to the order of the tasks, we grouped the participants into two groups. All participants completed both tasks with a counterbalanced order, determined by group. The first group (Group1),completed the reading task first and then the writing task. The second group first completed the writing task, then the reading task. However, both groups could see the live data recording only in the second task, regardless of whether this was reading or writing. The procedure is depicted in Figure 1.

3.2 Apparatus

To measure the brain activity, we used the FocusCalm [1] device. We chose this device because of its headband-like design that makes it easy to put on and take off without additional help. Although there are many medical-grade EEG devices on the market, we consider them far from wearable, meaning that the user would always require help to put them on and calibrate. Using FocusCalm helped us ensure ecological validity for a use case where tracking brain activity at the workplace could become a routine activity. The FocusCalm device uses three dry electrodes (Fpz, Fp1, Fp2 - based on the international 10-20 system[28]), targeting frontal brain regions involved in attention and emotional regulation. Aside from measuring brain activity, the device offer a variety of games, exercises, and meditations to support active practice of focus and calmness. For the purpose of our experiment, we just used the tracking option, which measures the brain activity while the device is being worn. The participants interacted with the data through the app, where they could see the visualization

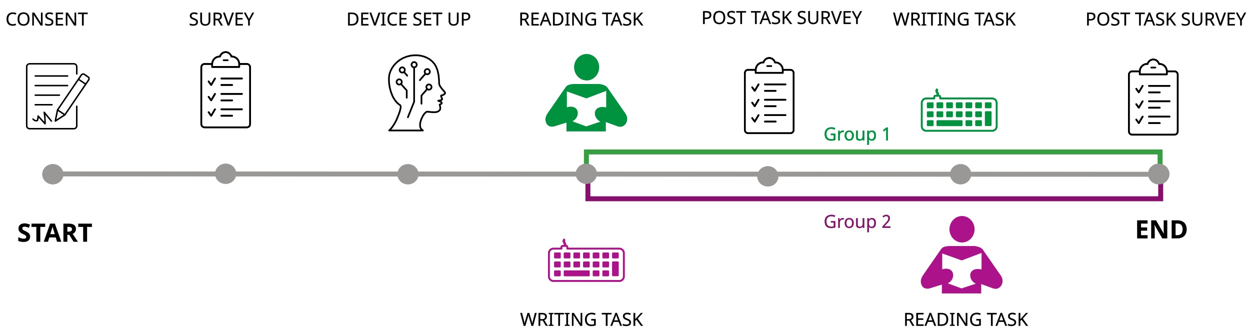


Figure 1: Workflow of the study involving two groups of participants with a counterbalanced task order. The workflow labeled with green (top) depicts the procedure applied to Group 1, and the one marked with pink (bottom) depicts the procedure for Group 2.

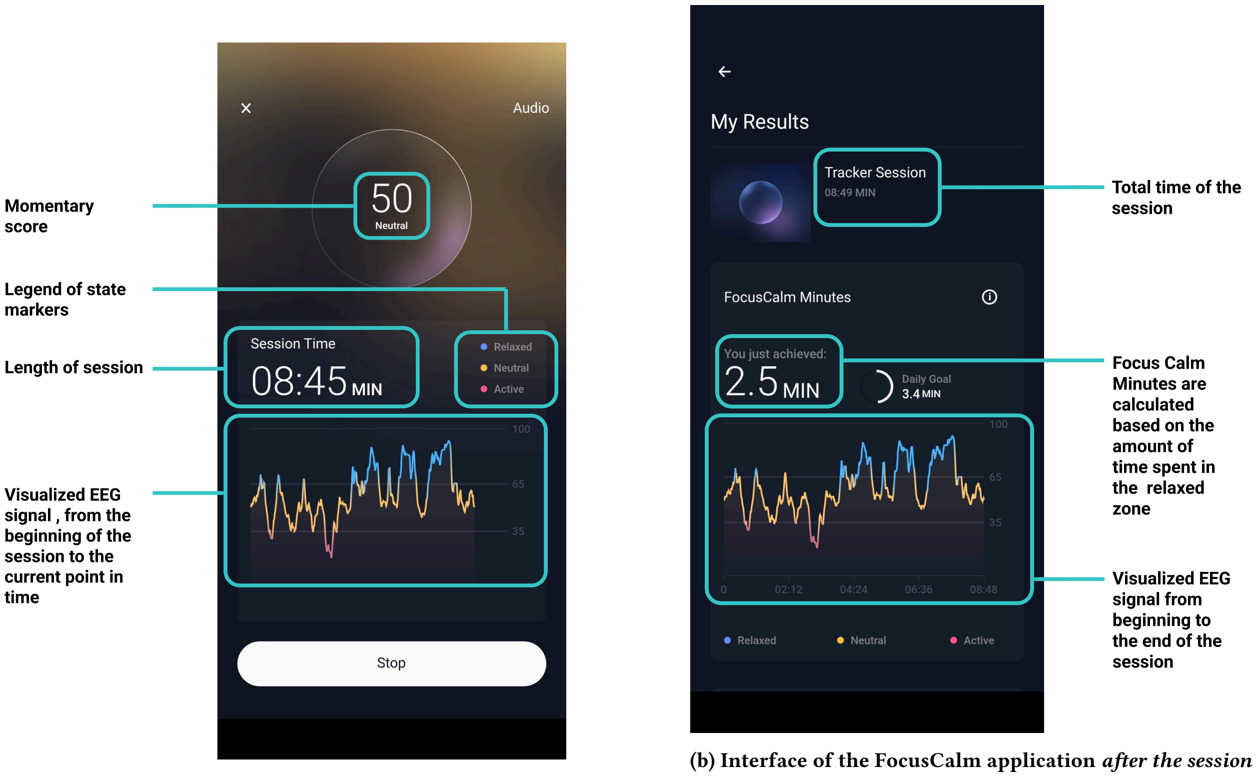
of the data recordings and the data translations into different scores as depicted in Figure 2a and Figure 2b. The core output of the devices is a so-called *FocusCalm Score*, ranging from 0 to 100, representing the user's mental state on a continuum from cognitive overload to calm focus. According to the manufacturer, the collected data is analyzed by a machine-learning AI algorithm, which analyzes over 1,000 data points per second to quantify the user's mental state as either focused/active or calm/relaxed. Values below 35 indicate high mental activity - busy and active brain and above 65 a calm, focused state [1]. The score is updated once per second, providing users with a near-continuous reflection of their attentional state.

3.3 Survey

To understand the effects of tracking the brain activity while completing reading and writing tasks, we asked the participants to complete a survey in several parts : demographics, current state of well-being, definitions of self-accomplishment and related metrics, assessing task difficulty and performance after the first task, neurofeedback reflections after the first task, assessing task difficulty and performance after the second task, neurofeedback reflections after the second task and final impressions of the neurofeedback sessions. First, we collected demographics and general information about the participant, such as age, gender, highest achieved education degree, and employment information. Then, the participants were asked to report on their current cognitive state by providing information on their stress levels, sleep, energy, and caffeine intake. Next, the participants shared their insights on how they define the sense of self-accomplishment, how often they reflect on it, if they think their focus levels impact their sense of self-accomplishment, and if they could relate to the hardships of not feeling accomplished despite working hard. The first task required reading, where the participants had to read a workshop proposal and write a short description of what they read. Following this task, the participants were asked to assess the perceived task difficulty, level of effort they put into the task, perceived productivity and focus levels during the task completion period, and self-assessed performance. These statements were rated on 5-point bipolar Likert scales (range: strongly disagree - strongly agree).

The next block of questions examined the interactions with the presented EEG data, whether they understood it, if they were surprised by the achieved scores, if the data helped them reflect and if they felt that tracking the brain activity may have impacted their performance. Then, the participants were presented with the writing task, where they were supposed to think about their most recent or favorite project and describe it in a text field. During the task completion, the participants had an opportunity to see the live neurofeedback scores and EEG signal visualizations in the app. After completing this task, we posed the same questions regarding the task difficulty as in the first task, i.e level of effort they put into the task, perceived productivity and focus levels during the task completion period and self-assessed performance.

Following this block of questions, the participants were also asked how often they looked at the neurofeedback score while executing the task, whether they perceived the live score influenced their performance, helped them adjust their focus and whether the score somewhat matched their own sense of focus/distraction. To better understand the effects of the score on their own focus perception, we asked the participants whether they felt like they were competing, whether the live score created pressure in performance and an open text interpretation of what score should be reached to reflect peak performance. To investigate the intensity of the effects that the presented score had evoked, we asked whether they had a clearer understanding of their cognitive efforts and whether this impacted their approach towards future cognitive tasks. Lastly, to understand the impact of focus levels on the perception of self-accomplishment, we asked the participants whether they defined self-accomplishment differently, after tracking their focus levels. The order of the questions remained the same, while the order of the tasks alternated per group, to better understand the effects of the type of task on the neurofeedback perceptions.



(a) Interface of the FocusCalm application *during* a brain activity tracking session, including the FocusCalm Score on the top, length of session time, and visualized EEG signal.

(b) Interface of the FocusCalm application *after the session* has been concluded, showing the total session time on the top, summary of calm time in relation to the goal, and visualized EEG signal.

Figure 2: FocusCalm mobile application interface with which the participants interacted.

3.4 Data Analysis

To analyze the qualitative data, we used Condens[1], a qualitative analysis tool, to organize and code the open-ended survey responses: (*"How do you personally define self-accomplishment in your work?", "Do you ever feel like you've worked hard but don't feel accomplished? Why do you think that happens?", "What score do you think should be reached to perform at your best and why?"*). Two researchers independently applied inductive, interpretive coding to the responses, allowing codes to emerge directly from the data through an iterative process of reading and re-reading [51]. This bottom-up approach helped surface categories and concepts that were not anticipated in advance [44]. After coding, the two researchers collaboratively reviewed and refined the codes, clustering them into broader categories to capture common patterns across responses. We structured and visualized the resulting coded data in Condens to support interpretation and provide an accessible overview of participants' perspectives.

3.5 Participants

We recruited N=20 participants, aged 22-32 ($M = 27.94$, $SD = 2.57$). Twelve participants identified as male, 7 as female, and one as diverse. The participants were recruited through Slack channels and word of mouth. For the purpose of this study, we only recruited knowledge workers, i.e., individuals whose work is knowledge-based and involves creating, applying, and distributing information [43]. Sixteen of the participants were full-time employees, 3 were part-time, and one was currently unemployed. Most of the participants (17) worked in higher education, 2 in the tech industry and 1 in marketing. Seventeen participants had achieved a master's degree and 3 of them a bachelor's degree. To mimic their usual setup in which they execute their daily tasks, we asked the participants to bring their laptops on which they completed the given tasks and a survey. Additionally, a working knowledge of English was required for the study. The participants participated voluntarily.

4 Results

4.1 Self-accomplishment at the workplace

To understand the role of self-accomplishment in the participants' work, we analyzed the qualitative answers as well as the

[1] https://app.condens.io (last accessed: 06/06/2025)

Likert scale responses. First, participants provided their definitions of self-accomplishment in their work. The majority defined self-accomplishment as an ***achievement of goals*** they've set for themselves [P5, P8, P9, P10, P11, P12, P13, P14, P16, P17, P18]. For example, P5 described it as "ticking tasks off a list" and P18 as "Sticking to the organized tasks I have defined, and finish them". Some of the participants had a less quantitative definition and described the feeling of self-accomplishment as ***having an impact, making a difference*** [P1, P3, P4, P2, P12, P15]. Some of these participants felt self-accomplishment from "making a significant advance in a project" [P3] or "building a skill" [P12]. Alongside the given definitions, some participants included ***overcoming challenges or solving a problem*** as a factor for higher self-accomplishment [P6, P10, P12, P15, P20] and others with ***achieving high quality results*** [P17,P19]. For instance, P17 expressed that they feel highly accomplished when they "... can achieve the goals I set for myself in a time frame that feels appropriate, and with good quality" and for P12 it is "mastering something hard". The participants were also asked to reflect on situations when they had worked hard but didn't feel accomplished. Most of the participants connected these situations with ***overwhelm*** [P5, P8, P9, P10, P13, P16, P17, P18, P19]. This feeling is often derived from "tasks taking too long to complete or longer than expected" [P16] or "trying to focus on multiple tasks, due to their high volume" [P10]. Additionally, some participants connected the feelings of low self-accomplishment with ***lack of tangible output*** [P1, P3, P4, P6, P12, P20]. Here, P1 noted: "Intangibles make it more difficult for me to feel accomplished. In knowledge work, for example, produced text makes me feel like I progressed". Thinking more about why this happens, a number of participants "blamed" the ***unexpected hurdles*** they encountered in their work, that interfered with their planning. This is mostly connected to not being able to find a solution for a certain problem within a given time, such as in P17's case: "I think mostly when tasks take way longer than I anticipated, I get frustrated and have a feeling of not getting anything done, and not accomplishing anything (or at least not as much as I hoped)".

When asked how often they experienced high self accomplishment, about two-thirds (65.7%) of participants reported that they often experienced a strong sense of accomplishment in their daily work and nearly one-third (31.3%) experience it sometimes ($M = 3.52, SD = 0.61$, range 1-5). When asked how often they reflect on self-accomplishment, only 35% reported that they reflect often. 15% reported that they reflect every day, while 20% of the participants also expressed that they rarely reflect ($M = 3.02, SD = 1.43$, range 1-5). Since we assumed that focus plays a role in knowledge work, we surveyed the participants to understand whether their focus has an impact on the perceived sense of accomplishment. A total of 42,1% stated that their ability to focus has a substantial impact on how accomplished they feel, while 26,3% believed that focus fully impacts their sense of self-accomplishment. In addition, 10,5% noted a moderate impact and 21,1% a slight impact, but none believed that focus has no impact on how accomplished they feel with their work ($M = 3.73, SD = 1.09$, range 1-5).

4.2 Current state

To evaluate the participants' cognitive state, we analyzed the reported data on the number of hours they've slept, tiredness, stress levels and caffeine intake. Most of the participants reported somewhat sufficient sleep, as 45% reported they've had 6-7 hours of sleep and 30% 7-8 hours. The majority of the participants (52,5%) reported that they feel moderately energetic on a scale from 1-5, whereas 24,6% felt neutral, ($M = 3.21, SD = 1.03$, range 1-5). When asked about their current stress level, a slight majority of the participants reported high stress (57,1%), 21,4% reported moderate stress and 17,9% mild stress. Only 3,6% reported that they are not stressed at all ($M = 2.94, SD = 1.07$, range 1-5). 40% of the participants have already had more than one cup of coffee or a caffeinated beverage prior to the study. Surprisingly, 35% of the participants had no caffeinated beverages and 25% had only one cup.

4.3 Reading task difficulty

In this section, we present the reflections on the reading task. An initial Shapiro-Wilk Test was conducted to determine whether the distribution of responses meets the assumptions of normality. Results indicated that none of the following items were normally distributed, with all p-values below the 0.5 significance threshold : *"The task was difficult."* ($W = 0.8298$, $p = .0025$), *"I felt focused during the task."* ($W = 0.7445$, $p = .0001$),*"I felt productive during the task."* ($W = 0.8644$, $p = .0094$), *"I think I performed well on the task."* ($W = 0.8739$, $p = .0138$), *"The task was mentally exhausting."* ($W = 0.8221$, $p = .0019$), *"I put in a high level of effort during the task."* ($W = 0.9016$, $p = .0442$). To determine any significant differences between group perceptions, we conducted a Mann-Whitney U Test for all items. Major differences in task difficulty assessment were observed between the two groups. The group that completed this task first (Group 1) found the task relatively easy to complete. The majority (60%) disagreed with the statement *"The task was difficult to complete"* and 20% strongly disagreed. On the other hand, Group 2 found the reading task much harder to complete, where the majority (60%) agreed with the above-mentioned statement. These differences were confirmed by the Mann-Whitney U test, $U = 16.0$, $p = .0073$.

Similar, but not significant effects (Mann-Whitney U Test) were observed for the statement *"The task was mentally exhausting"*, where 60% of Group 1 disagreed to this statement, but 60% of Group 2 agreed with it ($U = 26.5$, $p = .065$). The Likert Scale distributions are depicted in Figure 3 and Figure 4.

Below, we present the results from the reflections on their perceptions of their cognitive state during the task completion. A Mann-Whitney Test revealed no significant differences between the two groups for the items : *"I felt focused during the task."* ($U = 44.5$, $p = .668$), *"I felt productive during the task."* ($U = 59.0$, $p = .484$), *"I put in a high level of effort during the*

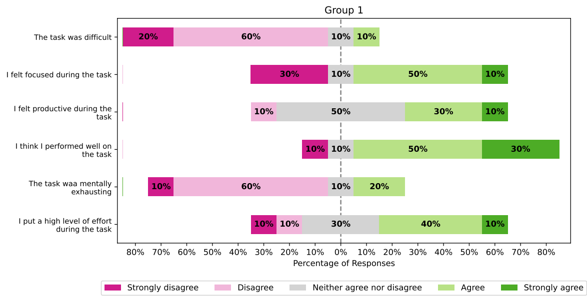


Figure 3: Likert-scale responses for Group 1 regarding the perceived effort and difficulty in the reading task.

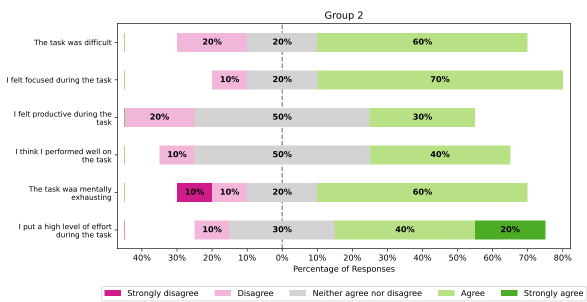


Figure 4: Likert-scale responses for Group 2 regarding the perceived effort and difficulty in the reading task.

task." (U = 41.0, p = .499), *"I think I performed well on the task."* (U = 73.5, p = .063).

4.4 Writing task difficulty

In this section, we present the reflections on the writing task. As for the items from the reading task, a Shapiro-Wilk Test was conducted to determine data normality. Here as well, none of the following items were normally distributed : *"The task was difficult."* (W = 0.8151, p = .0015), *"I felt focused during the task."* (W = 0.8010, p = .0009), *"I felt productive during the task."* (W = 0.6310, p = .0000), *"I think I performed well on the task."* (W = 0.7966, p = .0008), *"The task was mentally exhausting."* (W = 0.8004, p = .0009), *"I put in a high level of effort during the task."* (W = 0.8982, p = .0381). To observe group differences, we conducted a Mann-Whitney Test on the above mentioned items. For the perceived task difficulty, similar significant effects were observed in the writing task as in the reading task. Here, the majority of the participants (60%) that completed the writing task first (Group 2), somewhat disagreed that the task was difficult, where 60% of Group 1 strongly disagreed with the statement (U = 24.5, p = .042). For the items : *"I felt focused during the task."* (U = 52.0, p = .898), *"I felt productive during the task."* (U = 59.0, p = .425), *"I put in a high level of effort during the task."* (U = 51.5, p = .935), *"The task was mentally exhausting"* (U = 40.5, p = .455), *"I think I performed well on the task."* (U = 60.5, p = .420), no significant differences were

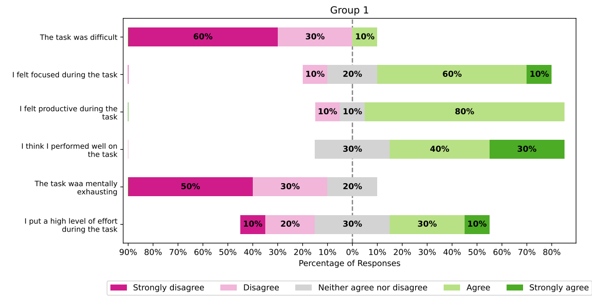


Figure 5: Likert-scale responses for Group 1 regarding the perceived effort and difficulty in the writing task.

found. The Likert Scale distributions are depicted in Figure 5 and Figure 6.

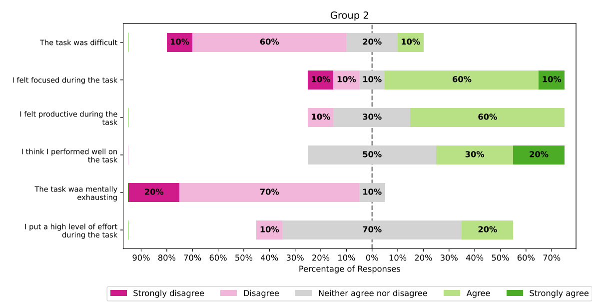


Figure 6: Likert-scale responses for Group 2 regarding the perceived effort and difficulty in the writing task.

4.5 Post-task neurofeedback reflections

After the first task, participants were able to see the data from the tracking session in the FocusCalm application. A Shapiro-Wilk Test confirmed the data was non-normally distributed for all items (Q15-Q17), and a Mann-Whitney revealed no significant differences in between groups' answers (see Table 1). As visualized in Figure 7 and Figure 8, there is very little difference to be noted in the responses between Group 1 and Group 2. The majority of both groups claimed to have understood the neurofeedback scores and believed that seeing the score in real time will have influence on their performance. Majorities of both groups had the tendency to dissagree that the neurofeedback changed their definition of accomplishment and that the scores create pressure for better performance. Group 1 showed more positive tendencies towards the statement *I feel that the neurofeedback score accurately reflected my state of focus*, however not significantly from Group 2. In line with these findings, Group 1 was also less surprised by their focus scores, where Group 2 was leaning more towards a surprise effect.

Table 1: Shapiro–Wilk and Mann–Whitney U Test Values for the Post-task NF reflections and During-task NF reflections

Item	Shapiro–Wilk Test		Mann–Whitney U Test	
	W	p	U	p
Post-task neurofeedback reflections				
Q15a: "I clearly understood what the neurofeedback score represented."	0.8109	0.0013	44.0	0.6457
Q15b: "Seeing the neurofeedback score create pressure to perform better in the next task."	0.8885	0.0252	45.0	0.7267
Q15c: "I believe that if I had seen the score in real time, it would have influenced my performance."	0.8201	0.0018	64.5	0.2551
Q15d: "Receiving the score (after the task) made me reflect on my focus and effort."	0.8938	0.0316	55.5	0.6978
Q15e: "I was surprised by my focus result."	0.8793	0.0172	37.5	0.3527
Q16: "I feel that the neurofeedback score accurately reflected my state of focus."	0.8265	0.0022	61.5	0.3581
Q17: "After seeing my focus feedback, I now feel more accomplished than before."	0.8341	0.0029	40.0	0.4543
During-task neurofeedback reflections				
Q19: "How often did you check your neurofeedback score during the task?"	0.8153	0.0015	57.5	0.5651
Q20: "How much did the neurofeedback score influence how you felt about your performance?"	0.8677	0.0107	47.5	0.8759
Q21: "Did the neurofeedback score in real-time help you adjust your focus?"	0.8094	0.0012	64.5	0.2592
Q22: "Did the neurofeedback data match your own sense of when you were focused and distracted?"	0.7802	0.0004	50.0	1.0000
Q23: "Did you question the accuracy of the neurofeedback data at any point?"	0.7439	0.0001	37.5	0.3017
Q24: "I feel like I was competing against the neurofeedback score rather than focusing on the task."	0.8312	0.0026	48.0	0.9058
Q26: "I feel more pressure knowing my focus score is being tracked in real-time."	0.8159	0.0009	29.0	0.0107
Q27: "I feel that seeing my focus data gave me a clearer understanding of my cognitive effort."	0.9163	0.0638		

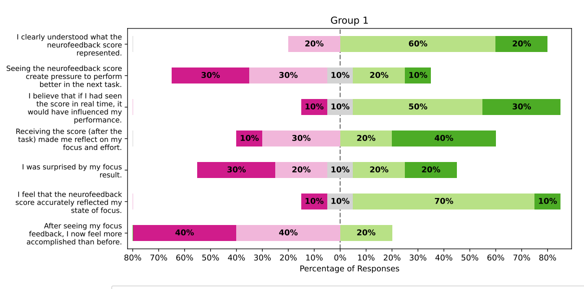


Figure 7: Likert-scale responses for Group 1 regarding post task neurofeedback reflections - Q15 - Q17.

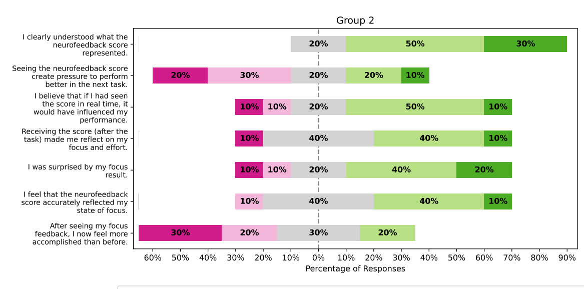


Figure 8: Likert-scale responses for Group 2 regarding post task neurofeedback reflections - Q15 - Q17.

4.6 During-task neurofeedback reflections

While completing the second task, participants had the chance to see the live scores in the application. Here we present the results of the survey that was presented after the task completion. We conducted a Shapiro-Wilk Test for the items of this section as well, revealing non-normally data distribution for items (Q19-Q26), and a Mann-Whitney revealed no significant differences in between groups answers (see Table 1). The Shapiro-Wilk Test revealed normal distributions for the item *Q27:"I feel that seeing my focus data gave me a clearer understanding of my cognitive effort."* ($W = 0.9163$, $p = .0638$). A further analysis was conducted with a t-test, revealing no significant differences between groups ($T - statistic = 0.0$, $p = 1.0$), due to equal group means (Group 1: $M : 3.1$, $SD = 1.28$, Group 2: $M : 3.1$, $SD = 1.19$).

As depicted in Figure 9 and Figure 10, the majorities of both groups seemed to look at the live scores occasionally, but they also occasionally questioned the accuracy of the data (Group 1: $M : 1.5$, $SD = 0.52$, Group 2: $M : 1.8$, $SD = 0.63$, range: 1-3).

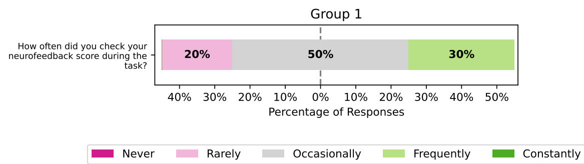


Figure 9: Likert-scale responses for Group 1 during task neurofeedback reflections - Q19.

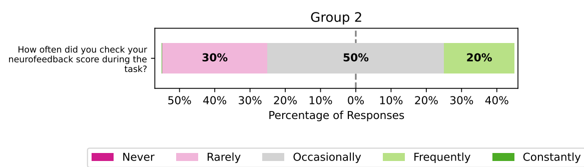


Figure 10: Likert-scale responses for Group 2 during task neurofeedback reflections - Q19.

In Figure 11 and Figure 12, we illustrate the tendencies of feeling pressure while being tracked in real-time for both groups, as well a slight positive attitude towards the helpfulness of the focus scores to convey the cognitive state of the user.

Interestingly, the pressure remained although the majority of participants in both groups had the tendency to question the accuracy of the data (Figure 13 and Figure 14).

Participants were also given an open text field to express their opinion on **which score do they need to achieve to show they are performing at their best**, while interpreting the data presented on the interface. One prevailing theme was ***the higher score, the better*** [P5, P6, P11, P20], where participants believed that these scores reflect a healthy and balanced workflow. On the other hand, some participants rather interpreted the visualized brain waves and believed that keeping them in the ***middle area suggests productiveness with ease*** [P9, P10, P14, P15]. A third cluster of participants had a different opinion, stating that the ***"active" state is desirable if not stressed*** [P7, P8, P17, P19].

4.7 Effects of tracking on personal perceptions

Extending on the post-task neurofeedback reflections, the participants reported on its impact on their cognitive perception and behavior. In this section, we analyzed items Q28 and

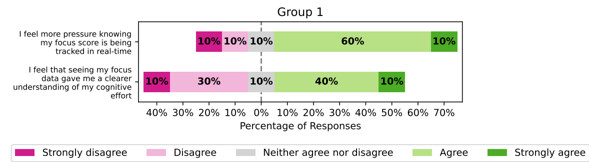


Figure 11: Likert-scale responses for Group 1 during task neurofeedback reflection - Q26 and Q27.

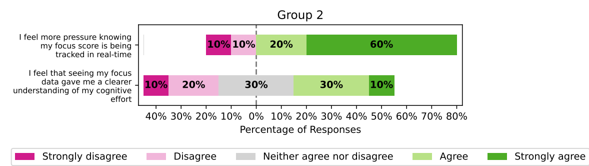


Figure 12: Likert-scale responses for Group 2 during task neurofeedback reflections - Q26 and Q27.

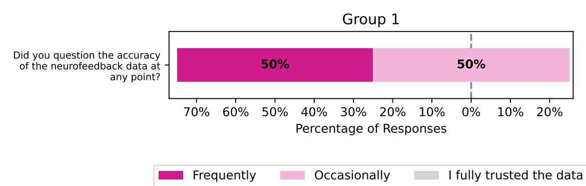


Figure 13: Likert-scale responses for Group 1 regarding during task neurofeedback reflections - Q23.

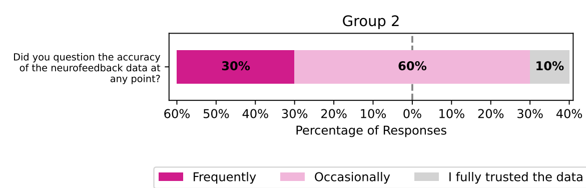


Figure 14: Likert-scale responses for Group 2 regarding during task neurofeedback reflections - Q23.

Q29. A Shapiro-Wilk Test revealed the data for both items is not normally distributed (Q28: $W = 0.7483$, $p = .0001$, Q29: $W = 0.8062$, $p = .0006$). A Mann-Whitney Test showed no significant differences for both items in the responses between the two groups (Q28: $U = 52$, $p = .9005$, Q29: $U = 48$, $p = .9041$). In Figure 15 and Figure 16, we depict stronger tendencies of unchanged definition of self-accomplishment for participants of both groups. Lastly, we note a slightly stronger positive, but not significant trend towards the usefulness of the focus scores for approach future cognitive tasks for Group 2.

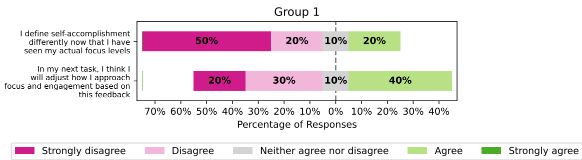


Figure 15: Likert-scale responses for Group 1 regarding the effects of neurofeedback on self-accomplishment definition and focus perceptions - Q28 and Q29.

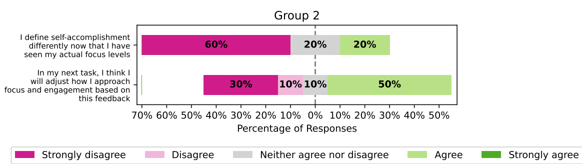


Figure 16: Likert-scale responses for Group 2 regarding the effects of neurofeedback on self-accomplishment definition and focus perceptions - Q28 and Q29.

5 Discussion

5.1 Limitations

While providing insights in neurofeedback in the workplace, we note several limitations of our study. First of all, we limited the participants to knowledge workers who mostly work in an academic environment. While the tasks that the participants completed within the study mimicked the tasks they accomplish in their everyday work, they don't encompass the full workflow that might include ideation sessions, group work or problem solving activities. Further on, the definition for knowledge workers encompasses a pool of different professions whose workflow might not match the one of an academic worker and therefore yield different results. Different insights might also be detected within groups with cognitive differences. For example, neurodivergent individuals, individuals who suffer burnout, high anxiety or elderly individuals who are experiencing age-related cognitive changes. Given the limited availability of the participants, they completed only two tasks while wearing the device, however, repeated tracking over longer time spans could have yielded different results. Further, we only recruited non-expert participants, i.e., individuals with no experience of neurofeedback. We hypothesize that there might be different outcomes when conducting the study with participants who already have experience with neurofeedback or rather do brain activity-tracking regularly. Their motivation should be vastly different from the present group as well. Finally, the participants interpreted the data visualization from the FocusCalm interface over which we had no control. There was a lot of variance in the data interpretation by the participants in both tasks, which points out the need for better understanding of how users interpret the given data visualizations as well as the given metrics that reflect their cognitive activity. This is a strong limitation to this work, since different presentations of the data and different metrics can heavily influence the user perceptions and understanding of this data.

5.2 Knowledge workers' definitions of self-accomplishment

As related work suggests, quantifying knowledge work seems challenging due to its intangible nature. However, measuring the accomplished work is an important factor for achieving a strong feeling of self-accomplishment. In our study, the participants reported stable definitions of self-accomplishment before the neurofeedback sessions. As reported in subsection 4.1, the vast majority used goal completion as a metric that defines the level of self-accomplishment [17]. Some definitions included overcoming challenges or achieving high quality results, however none of the participants failed to describe what makes them feel accomplished. They also reported on situations when they don't feel accomplished, mentioning feeling overwhelmed as the main reason, due to trying to focus on multiple tasks at a time or tasks taking too long to complete [4, 14, 38, 40]. A number of participants also mentioned the lack of tangible output and unexpected hurdles on the way. This leads us to believe that although not in a uniform way, all participants have found a way to quantify their work and let it directly impact their sense of self-accomplishment. They also seem to reflect and evaluate the levels of self-accomplishment frequently in their day-to-day work, which gives it the potential to act as a powerful driver of motivation, satisfaction and a driver for improving performance [11, 59]. Another factor that impacts the feeling of self-accomplishment is the ability to focus [7]. At the beginning, all participants believed that their ability to focus at work plays an important role in the perceived level of accomplishment, however they later reported that seeing their focus scores during the task completion did not have an impact on their previously stated definition of self-accomplishment. Therefore, the quantified focus levels were not as important for the definition, but rather as a main driver to produce more output and incorporate insights of their cognitive states in their self-reflection [22, 59].

5.3 The influence of neurofeedback on task performance and the definition of self-accomplishment

For many participants, seeing the focus score (whether during or after the task) prompted reflection on how well they thought they were doing [12, 58, 63]. Some participants reported that the scores validated their internal sense of focus, helping them feel more confident in their effort and performance [21, 58]. For example, a majority of Group 1 agreed or strongly agreed that the neurofeedback score reflected their actual state during the task, meaning that the feedback was useful in reinforcing the subjective perceptions of cognitive engagement. The participants were also quite positivistic about the usefulness of the neurofeedback scores to provide insights in their cognitive states, as shown in Figure 11 and Figure 12.

However, not all participants trusted the accuracy of the data. There was significant skepticism expressed towards the accuracy of the scores by the majorities of participants in both groups, as depicted in Figure 13 and Figure 14. This statement is quite contradictory to the previous one and could be interpreted as mistrust due to the novelty of the technology [34, 36], since most of the participants were using it for the first time. Additionally, performance pressure emerged as a key theme. Some participants reported that seeing the score, particularly in real time, introduced an element of performance anxiety. While not universal, this effect was present across both groups. About 60% of participants in both groups said they felt more pressure knowing they were being tracked live, which could have influenced their focus levels or emotional state during the task [24, 48]. Supported by the results in subsection 4.5, where the participants stated that seeing the neurofeedback score after the task rather did not create pressure for future cognitive tasks and that seeing it live would have possibly influenced their performance, we suggest that designers should opt out of presenting the score during the tracking, but rather after - to support post-task reflections. Presenting the score during a cognitive task seems to create pressure in performance and therefore influencing the user's attention to the task, since they cannot simultaneously focus on monitoring their score and their task. Real-time feedback would also be counter productive in this case, as focus is not something we can steer so easily as physical abilities.

Overall, while the neurofeedback did not redefine what participants considered an accomplishment, it rather influenced how they assessed their moment-to-moment performance. This supports the idea that external metrics like neurofeedback can shape perceptions of cognitive effort, even if they do not reshape intrinsic motivations or values.

5.4 Task order effects on neurofeedback perceptions

Task order played a significant role in how participants perceived the reading and writing tasks. For example, participants who performed the reading task second found it significantly more exhausting and difficult than those who did it first. Both groups found the writing task relatively easy to complete, implying that the reading task was generally perceived as more difficult [39, 55]. Essentially, understanding and evaluating someone else's work is more difficult than explaining one's own - however, it can also mean that the first task set the difficulty baseline and impacted the perceptions of the second task. As presented in subsection 4.3 and subsection 4.4, the other metrics such as perceived performance, productivity and invested effort were complimentary to the perceived task difficulty. For example, the participants who completed the reading task as second (Group 2), suffered higher mental exhaustion and were less happy about their performance. Ultimately, the subjective performance assessments had no effect on the neurofeedback score perceptions. However, this disconnect between subjective task experience and perceived neurofeedback suggests that participants may have interpreted the feedback independently of their moment-to-moment effort or emotional state. Additionally, this separation raises important considerations for how neurofeedback is integrated into cognitively demanding tasks: while it may offer a layer of insight, it does not necessarily align with how participants feel about their performance or effort. Future research might explore whether aligning feedback more explicitly with perceived effort or affective state enhances user engagement or self-reflection.

6 Summary and Conclusion

In this work, we explore initial insights on how real-time neurofeedback affects knowledge workers' perceptions of focus, task performance, and self-accomplishment. Our findings reveal that knowledge workers already had individual, but stable definitions of self-accomplishments and have found ways to quantify the amount of completed work, despite its intangible nature. Their definitions of self-accomplishment revolve around goal completion and quality of output. While not being a part of the definition, participants admitted that their ability to focus impacts the sense of accomplishment, implying that the production and quality of output depend on the ability to focus. The short neurofeedback session and introduction to their focus score did not change their pre-formed definitions of self-accomplishment, but rather offered insights into their cognitive performance which prompted self-reflection. The introduced scores were also met with some skepticism, where the participants doubted the accuracy of the scores. Some participants stated that the scores matched their internal perception, but others reported a mismatch. This individual variability could be connected to the fact that participants interpreted their scores very subjectively, alongside with their interpretation of which score indicates good performance and its variability during the task completion process. While the scores were found useful to get a clearer understanding of their cognitive efforts, having the live scores on display during a task was found pressuring by the participants. If on display, they had a tendency to feel like they were competing with the score, regardless of the type of task they were completing. This implies that while informative, displaying the scores can be distracting from the main task and to some extent, counterproductive. In summary, we conclude that while real-time neurofeedback on focus levels did not significantly alter how knowledge workers define self-accomplishment, it still helped them gain insights into their cognitive state while performing a mundane task. Some participants expressed trust in the measured scores but some met them with skepticism. This variability in interpretations also highlights the need for more explainable and standardized metrics, that are not dependent on a particular product. Ultimately, neurofeedback served more as a real-time reflective aid, shaping how individuals interpret their performance, rather than transforming how they evaluate and define accomplishment in their day-to-day work.

References

[1] [n. d.]. *Focus Calm*. https://focuscalm.com

[2] [n. d.]. *muse*. https://choosemuse.com/?srsltid=AfmBOoqzmHuyZhwrCtSnEBj3-nVdZZBf6vgprLjxJRMFvBi5fROqGm4o

[3] [n. d.]. *Neurosity*. https://neurosity.co/#subscribe-to-newsletter

[4] Yoana Ahmetoglu, Duncan Brumby, and Anna Cox. 2024. Bridging the Gap Between Time Management Research and Task Management App Design: A Study on the Integration of Planning Fallacy Mitigation Strategies. In *Proceedings of the 3rd Annual Meeting of the Symposium on Human-Computer Interaction for Work* (Newcastle upon Tyne, United Kingdom) *(CHIWORK '24)*. Association for Computing Machinery, New York, NY, USA, Article 12, 14 pages. https://doi.org/10.1145/3663384.3663404

[5] Albert Bandura. 1986. The explanatory and predictive scope of self-efficacy theory. *Journal of Social and Clinical Psychology* (1986).

[6] Srabani Banerjee and Charlene Argáez. 2017. *Neurofeedback and Biofeedback for Mood and Anxiety Disorders: A Review of Clinical Effectiveness and Guidelines*. Canadian Agency for Drugs and Technologies in Health, Ottawa (ON).

[7] Erica Baranski, Casey Lindberg, Brian Gilligan, Julia M. Fisher, Kelli Canada, Judith Heerwagen, Kevin Kampschroer, Esther Sternberg, and Matthias R. Mehl. 2023. Personality, workstation type, task focus, and happiness in the workplace. *Journal of Research in Personality* 103 (2023), 104337. https://doi.org/10.1016/j.jrp.2022.104337

[8] Beatrix Barth, Kerstin Mayer-Carius, Ute Strehl, Sarah N Wyckoff, Florian B Haeussinger, Andreas J Fallgatter, and Ann-Christine Ehlis. 2021. A randomized-controlled neurofeedback trial in adult attention-deficit/hyperactivity disorder. *Scientific Reports* 11, 1 (Aug. 2021), 16873.

[9] Katherine Boere, Kent Hecker, and Olave E Krigolson. 2023. Validation of a mobile fNIRS device for measuring working memory load in the prefrontal cortex. *Int J Psychophysiol* 195 (Dec. 2023), 112275.

[10] Katherine Boere, Kent Hecker, and Olave E Krigolson. 2023. Validation of a mobile fNIRS device for measuring working memory load in the prefrontal cortex. *Int J Psychophysiol* 195 (Dec. 2023), 112275.

[11] Nathan A. Bowling, Qiang Wang, Han Ying Tang, and Kellie D. Kennedy. 2010. A comparison of general and work-specific measures of core self-evaluations. *Journal of Vocational Behavior* 76, 3 (2010), 559–566. https://doi.org/10.1016/j.jvb.2010.01.008

[12] Eun Kyoung Choe, Bongshin Lee, Haining Zhu, Nathalie Henry Riche, and Dominikus Baur. 2017. Understanding self-reflection: how people reflect on personal data through visual data exploration. In *Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare* (Barcelona, Spain) *(PervasiveHealth '17)*. Association for Computing Machinery, New York, NY, USA, 173–182. https://doi.org/10.1145/3154862.3154881

[13] Thomas Davenport. 2005. Thinking for A Living: How to Get Better Performance and Results from Knowledge Workers. (01 2005).

[14] Dominique Demougin and Carsten Helm. 2023. Overwhelmed by routine tasks: A multitasking principal agent perspective. *Journal of Economic Behavior & Organization* 216 (2023), 654–669. https://doi.org/10.1016/j.jebo.2023.10.021

[15] P F Drucker. 1991. The new productivity challenge. *Harv Bus Rev* 69, 6 (Nov. 1991), 69–69.

[16] Peter F. Drucker. 1999. Knowledge-Worker Productivity: The Biggest Challenge. *California Management Review* 41, 2 (1999), 79–94. https://doi.org/10.2307/41165987

[17] Joan L. Duda. 2004. Goal Setting and Achievement Motivation in Sport. In *Encyclopedia of Applied Psychology*, Charles D. Spielberger (Ed.). Elsevier, New York, 109–119. https://doi.org/10.1016/B0-12-657410-3/00804-7

[18] Abdulrahman K Eesee, Vera Varga, György Eigner, and Tamás Ruppert. 2025. Impact of work instruction difficulty on cognitive load and operational efficiency. *Scientific Reports* (2025).

[19] Andrew J. Elliot and Holly A. McGregor. 1999. Test Anxiety and the Hierarchical Model of Approach and Avoidance Achievement Motivation. *Journal of Personality and Social Psychology* 76, 4 (1999), 628–644. https://doi.org/10.1037/0022-3514.76.4.628

[20] Daniel A. Epstein, An Ping, James Fogarty, and Sean A. Munson. 2015. A lived informatics model of personal informatics. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (Osaka, Japan) *(UbiComp '15)*. Association for Computing Machinery, New York, NY, USA, 731–742. https://doi.org/10.1145/2750858.2804250

[21] Xiaowei Fan, Jun Fan, and Jianglu Li. 2022. The Effect of Presentation Characteristics of "Quantified Self" Data on Consumers' Continuance Participation Intention: An Empirical Study Based on Health-Related Apps. *Psychol Res Behav Manag* 15 (Oct. 2022), 2859–2877.

[22] Shan Feng, Matti Mäntymäki, Amandeep Dhir, and Hannu Salmela. 2021. How Self-tracking and the Quantified Self Promote Health and Well-being: Systematic Review. *J Med Internet Res* 23, 9 (Sept. 2021), e25171.

[23] Edith Galy, Magali Cariou, and Claudine Mélan. 2012. What is the relationship between mental workload factors and cognitive load types? *International Journal of Psychophysiology* 83, 3 (2012), 269–275. https://doi.org/10.1016/j.ijpsycho.2011.09.023

[24] David John Harris, Tom Arthur, Samuel James Vine, Harith Rusydin Abd Rahman, Jiayi Liu, Feng Han, and Mark R. Wilson. 2023. The effect of performance pressure and error-feedback on anxiety and performance in an interceptive task. *Frontiers in Psychology* Volume 14 - 2023 (2023). https://doi.org/10.3389/fpsyg.2023.1182269

[25] Hong He, Yunyun Chen, Ting Li, Hui Li, and Xuemin Zhang. 2023. The role of focus back effort in the relationships among motivation, interest, and mind wandering: an individual difference perspective. *Cognitive Research: Principles and Implications* (July 2023).

[26] Michael L.A. Hsu, Sheng-Tsung Hou, and Hsueh-Liang Fan. 2011. Creative Self-Efficacy and Innovative Behavior in a Service Setting: Optimism as a Moderator. *The Journal of Creative Behavior* 45, 4 (Dec. 2011), 258–272. https://doi.org/10.1002/j.2162-6057.2011.tb01430.x

[27] Gianpaolo Iazzolino and Domenico Laise. 2018. Knowledge worker productivity: is it really impossible to measure it? *Measuring Business Excellence* 22 (10 2018). https://doi.org/10.1108/MBE-06-2018-0035

[28] Herbert H Jasper. 1958. The ten-twenty electrode system of the International Federation. *Electroencephalogr. Clin. Neurophysiol.* 10 (1958), 370–375.

[29] Tugba Karaboga. 2023. Creativity as a mediator between personal accomplishment and task performance: A multigroup analysis based on gender during the COVID-19 pandemic. *Current Psychology* 42, 15 (Jan. 2023), 12517–12529. https://doi.org/.org/10.1007/s12144-021-02510-z Publisher: Springer Science and Business Media LLC.

[30] Young-Ho Kim, Eun Kyoung Choe, Bongshin Lee, and Jinwook Seo. 2019. Understanding Personal Productivity: How Knowledge Workers Define, Evaluate, and Reflect on Their Productivity. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3290605.3300845

[31] Charlotte Kobiella, Yarhy Said Flores López, Franz Waltenberger, Fiona Draxler, and Albrecht Schmidt. 2024. "If the Machine Is As Good As Me, Then What Use Am I?" – How the Use of ChatGPT Changes Young Professionals' Perception of Productivity and Accomplishment. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–16. https://doi.org/10.1145/3613904.3641964

[32] Charlotte Kobiella, Teodora Mitrevska, Albrecht Schmidt, and Fiona Draxler. 2025. When Efficiency Meets Fulfillment: Understanding Long-Term LLM Integration in Knowledge Work. (2025).

[33] Simon H Kohl, David MA Mehler, Michael Lührs, Robert T Thibault, Kerstin Konrad, and Bettina Sorger. 2020. The potential of functional near-infrared spectroscopy-based neurofeedback—a systematic review and recommendations for best practice. *Frontiers in neuroscience* 14 (2020), 594.

[34] Nataliia Korotkova, Jos Benders, Patrick Mikalef, and David Cameron. 2023. Maneuvering between skepticism and optimism about hyped technologies: Building trust in digital twins. *Information & Management* 60 (03 2023), 103787. https://doi.org/10.1016/j.im.2023.103787

[35] Hao-Ping (Hank) Lee, Advait Sarkar, Lev Tankelevitch, Ian Drosos, Sean Rintel, Richard Banks, and Nicholas Wilson. 2025. The Impact of Generative AI on Critical Thinking: Self-Reported Reductions in Cognitive Effort and Confidence Effects From a Survey of Knowledge Workers. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 1121, 22 pages. https://doi.org/10.1145/3706598.3713778

[36] Roman Lukyanenko, Wolfgang Maass, and Veda C Storey. 2022. Trust in artificial intelligence: From a Foundational Trust Framework to emerging research opportunities. *Electronic Markets* 32, 4 (Dec. 2022), 1993–2020.

[37] Ewa Lux, Marc TP Adam, Verena Dorner, Sina Helming, Michael T Knierim, and Christof Weinhardt. 2018. Live biofeedback as a user interface design element: A review of the literature. *Communications of the Association for Information Systems* 43, 1 (2018), 18.

[38] Selin A Malkoc and Gabriela N Tonietto. 2019. Activity versus outcome maximization in time management. *Current Opinion in Psychology* 26 (2019), 49–53. https://doi.org/10.1016/j.copsyc.2018.04.017 Time.

[39] Thomas Mangin, Michel Audiffren, Alison Lorcery, Francesco Mirabelli, Abdelrhani Benraiss, and Nathalie André. 2022. A plausible link between the time-on-task effect and the sequential task effect. *Frontiers in Psychology* Volume 13 - 2022 (2022). https://doi.org/10.3389/fpsyg.2022.998393

[40] Gloria Mark, Daniela Gudith, and Ulrich Klocke. 2008. The cost of interrupted work: More speed and stress. *Conference on Human Factors in Computing Systems - Proceedings*, 107–110. https://doi.org/10.1145/

1357054.1357072
[41] Christina Maslach, Susan Jackson, and Michael Leiter. 1997. The Maslach Burnout Inventory Manual. In *Evaluating Stress: A Book of Resources*. Vol. 3. 191–218.
[42] Christina Maslach and Susan E. Jackson. 1981. The Measurement of Experienced Burnout. *Journal of Organizational Behavior* 2, 2 (April 1981), 99–113. https://doi.org/10.1002/job.4030020205
[43] Ludmila Mládková, Jarmila Zouharová, and Jindřich Nový. 2015. Motivation and Knowledge Workers. *Procedia - Social and Behavioral Sciences* 207 (2015), 768–776. https://doi.org/10.1016/j.sbspro.2015.10.163 11th International Strategic Management Conference.
[44] Hendrik Müller, Aaron Sedley, and Elizabeth Ferrall-Nunge. 2014. Survey Research in HCI. In *Ways of Knowing in HCI*, Judith S. Olson and Wendy A. Kellogg (Eds.). Springer, New York, NY, 229–266. https://doi.org/10.1007/978-1-4939-0378-8_10
[45] Tomoya Nakai, Hironori Nakatani, Chihiro Hosoda, Yulri Nonaka, and Kazuo Okanoya. 2017. Sense of Accomplishment Is Modulated by a Proper Level of Instruction and Represented in the Brain Reward System. *PLOS ONE* 12, 1 (Jan. 2017), e0168661. https://doi.org/10.1371/journal.pone.0168661
[46] Sebastian Putz, Alexander Mertens, Lewis Chuang, and Verena Land Nitsch. 2024. Physiological Predictors of Operator Performance: The Role of Mental Effort and Its Link to Task Performance. *Hum Factors* (Oct. 2024).
[47] Yuri Ramírez and David Nembhard. 2004. Measuring Knowledge Worker Productivity: A Taxonomy. *Journal of Intellectual Capital* 5 (12 2004), 602–628. https://doi.org/10.1108/14691930410567040
[48] Daniel Ravid, Jerod White, David Tomczak, Ahleah Miles, and Tara Behrend. 2022. A meta-analysis of the effects of electronic performance monitoring on work outcomes. *Personnel Psychology* 76 (04 2022), 5–40. https://doi.org/10.1111/peps.12514
[49] John Rooksby, Mattias Rost, Alistair Morrison, and Matthew Chalmers. 2014. Personal tracking as lived informatics. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 1163–1172. https://doi.org/10.1145/2556288.2557039
[50] Joshua Sabio, Nikolas S Williams, Genevieve M McArthur, and Nicholas A Badcock. 2024. A scoping review on the use of consumer-grade EEG devices for research. *Plos one* 19, 3 (2024), e0291186.
[51] Johnny Saldaña. 2009. *The Coding Manual for Qualitative Researchers*. Sage Publications Ltd, Thousand Oaks, CA. xi, 223 pages.
[52] Christina Schneegass, Max L Wilson, Horia A. Maior, Francesco Chiossi, Anna L Cox, and Jason Wiese. 2023. The Future of Cognitive Personal Informatics. In *Proceedings of the 25th International Conference on Mobile Human-Computer Interaction* (Athens, Greece) *(MobileHCI '23 Companion)*. Association for Computing Machinery, New York, NY, USA, Article 35, 5 pages. https://doi.org/10.1145/3565066.3609790
[53] Mark S. Schwartz and Frank Andrasik. 2017. *Biofeedback: A Practitioner's Guide* (4th ed.). The Guilford Press.
[54] Pamela Tierney and Steven Farmer. 2002. Creative Self-Efficacy: Its Potential Antecedents and Relationship to Creative Performance. *Academy of Management Journal* 45 (Dec. 2002), 1137–1148. https://doi.org/10.2307/3069429
[55] Richard Tindle and Mitchell G Longstaff. 2015. Writing, Reading, and Listening Differentially Overload Working Memory Performance Across the Serial Position Curve. *Adv Cogn Psychol* 11, 4 (Dec. 2015), 147–155.
[56] Nadja Tschentscher, Julia C. Tafelmaier, Christian F. J. Woll, Oliver Pogarell, Maximilian Maywald, Larissa Vierl, Katrin Breitenstein, and Susanne Karch. 2024. The Clinical Impact of Real-Time fMRI Neurofeedback on Emotion Regulation: A Systematic Review. *Brain Sciences* 14, 7 (2024). https://doi.org/10.3390/brainsci14070700
[57] Kerrie Unsworth. 2005. Creative Requirement: A Neglected Construct in the Study of Employee Creativity? *Group & Organization Management* 30 (Oct. 2005), 541–560. https://doi.org/10.1177/1059601104267607
[58] Elisabeth T. Kersten van Dijk, Joyce H.D.M. Westerink, Femke Beute, and Wijnand A. IJsselsteijn and. 2017. Personal Informatics, Self-Insight, and Behavior Change: A Critical Review of Current Literature. *Human–Computer Interaction* 32, 5-6 (2017), 268–296. https://doi.org/10.1080/07370024.2016.1276456
[59] Mariëtte H. van Loon. 2019. *Self-Assessment and Self-Reflection to Measure and Improve Self-Regulated Learning in the Workplace*. Springer International Publishing, Cham, 1389–1408. https://doi.org/10.1007/978-3-319-94532-3_88
[60] Nikolaus Weiskopf. 2012. Real-time fMRI and its application to neurofeedback. *NeuroImage* 62, 2 (2012), 682–692. https://doi.org/10.1016/j.neuroimage.2011.10.009 20 YEARS OF fMRI.
[61] Max L Wilson, Serena Midha, Horia A. Maior, Anna L Cox, Lewis L Chuang, and Lachlan D Urquhart. 2022. SIG: Moving from Brain-Computer Interfaces to Personal Cognitive Informatics. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI EA '22)*. Association for Computing Machinery, New York, NY, USA, Article 163, 4 pages. https://doi.org/10.1145/3491101.3516402
[62] Max L Wilson, Jwan Shaban, Horia A. Maior, Christina Schneegass, and Anna L Cox. 2024. The CHI'24 Workshop on the Future of Cognitive Personal Informatics. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI EA '24)*. Association for Computing Machinery, New York, NY, USA, Article 491, 6 pages. https://doi.org/10.1145/3613905.3636296
[63] Maria Wirzberger, Anastasia Lado, Mike Prentice, Ivan Oreshnikov, Jean-Claude Passy, Adrian Stock, and Falk Lieder. 2024. Optimal feedback improves behavioral focus during self-regulated computer-based work. *Scientific Reports* 14, 1 (Feb. 2024), 3124.
[64] Christopher A. Wolters and Stacy G. Daugherty. 2007. Goal structures and teachers' sense of efficacy: Their relation and association to teaching experience and academic level. *Journal of Educational Psychology* 99, 1 (Feb. 2007), 181–193. https://doi.org/10.1037/0022-0663.99.1.181