When High Mental Workload is Good and Low Mental Workload is Bad

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ABSTRACT

Brain-related wearables are now freely available on the market, and with even wrist-worn devices making estimates about cognitive activity, understanding cognitive personal informatics has become a pressing issue. Mental Workload is an emotionally agnostic concept that is potentially a parallel to tracking physical activity, which is typically naively considered to be bad if it is high and good if it is low. In this paper we report tasks and their relationship to three dimensions: high vs low, good vs bad, long vs short. We contribute examples of both good and bad high mental workload, as well as good and bad low mental workload, along with examples of long and short high mental workload, and long and short low mental workload.

CCS CONCEPTS

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

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1 INTRODUCTION

With the arrival of consumer brain-focused wearables for as little as £250, we are now in a place where we need to understand more about *cognitive* personal informatics [14]. This is a move from a well established self-tracking of e.g. mood [1] to understanding what data recorded about our brain activity may say about us, or indeed how it might be interpreted in terms of cognitive activity. Even wrist-worn wearables are starting to make assessments about our stress levels (e.g. Garmin stress tracking), or when we might need to take a break (e.g. Apple watch breathing breaks). There is also great concern about the socio-technical ethics that will emerge as this data is being captured and processed by large tech companies [6], and potentially used by employers to increase profits[1].

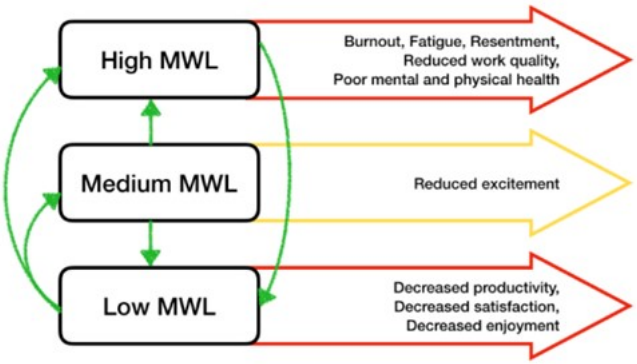

Figure 1: The Mental Workload Cycle (Midha et al 2022b [7])

Collecting and analysing physical activity through wearables such as smart watches is now a common practice, where monitoring fitness via mobile apps has been the centre of attention for the last decade [8]. The study of how people manage this kind of data about themselves over time is called Personal Informatics [4], where people tend to pass through phases of collecting, understanding, and reflecting on what the data says about them. Habit formation through technology [11] emphasises the importance of personalisation for such mobile apps, where people prefer keeping track of their own data especially that they now are familiar with such technologies.

Of the various forms of cognitive activity that could be tracked in future cognitive personal informatics, we argue that Mental Workload [10] is a valuable and emotionally agnostic conceptual parallel to initially compare to physical activity tracking. Where many studies also try to use physiological activity to measure alternatives like stress [2], we consider that stress is a capability judgement on being able to handle mental workload [3], which itself is the activity that we want actually to track. Using the comparison to physical activity, however, where technology can classify types of physical activity, wearables do not measure whether we feel good or bad about our ability to achieve that physical activity.

[1] Vice.com commentary on the profits reported from tracking employee EEG data

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Mental Workload is an empirically validated construct, where research has focused almost exclusively on estimating the mental workload experienced during a task [5, 13] in order to make sure that people are not too overloaded to complete it. Our own recent research has examined the role that mental workload plays in everyday life [7]; across a day, a week, or long-term. This prior work proposed a mental workload cycle, as shown in (Figure 1), where people manage their mental workload across a day in cycles of high and low mental workload in order to e.g. reduce fatigue at the end of the day. The aim of this new work is to understand more about peoples experiences of those cycles by gathering grounded data about tasks, the levels of mental workload they demand, their length, and how people feel about them. This paper presents early insights into those tasks, looking particularly at what tasks were submitted in the studies and how they were categorised.

2 STUDY DESIGN

The data presented in this workshop paper is based upon two studies of the relationship between mental workload and everyday life. Both studies combined a week of recording identifying the mental workload level involved in completing tasks or activities through the use of chatbots, followed by an interview about their experiences. This paper presents some early insights into the mental workload of tasks from the data recorded during the pre-interview week. In both studies, ethics was reviewed by the School of Computer Science in the University of Nottingham, and participants were remunerated with a £10 amazon voucher.

Group A - Mental Workload Planning. 27 students took part in planning their work days using a bot that was built in slack. At the start of each day, participants interacted with the slack bot to fill in a) fixed time-point tasks (such as meetings), and b) other tasks to complete that day. The bot asked participants to categorise these tasks by length (short, medium, long) and mental workload (low, medium, high). The subsequent interviews referred to this data to help participants reflect on how they organise their work and perhaps manage mental workload each day. This paper presents an insight into the tasks they provided to the bot, and how they were categorised in terms of length and level of mental workload.

Group B - Mental Workload Experience Sampling. 20 students took part in an experience sampling method [12] study, where a discord bot would send them a message approximately four times a day to ask four specific questions: 1) what they were doing at the time of the ping (an open text reply), 2) what mental workload level it involved (scale 1-5, where 5 is high), 3) how they felt about it (unhappy, neutral, pleased), and 4) why they felt this way (open text reply). Participants were then interviewed about the replies they provided to the bot over the week. This paper presents an insight into the activities they were doing at the sample points, and how they were categorised in terms of mental workload and how they felt about it.

3 RESULTS

We present an overview of tasks and activities reported from both studies as an early stage of data analysis. In the two subsections below, we contribute examples of both good and bad high mental workload, as well as good and bad low mental workload, along with examples of long and short high mental workload, and long and short low mental workload.

3.1 Length and Mental Workload

Table 2 shows a 3-by-3 grid of example daily tasks that were provided to the slack bot at the start of each day. There is often a presumed relationship such that bigger tasks are harder and thus involve higher mental workload, and that these sit in comparison to shorter easier tasks. This false assumption is counter to the theoretical basis of mental workload which simply relates to the demand of a task and the mental workload experienced by the person trying to achieve it. This table, therefore, provides an interesting set of grounded examples of tasks of different sizes for high, medium, and low mental workload levels.

Short high mental workload tasks typically involved check and action type tasks, often with higher subsequent consequence. Planning priorities, and experiment check are examples where subsequent work is dependent on an action now that requires high mental workload. Comparatively, longer high mental workload tasks were typically longer focus tasks, such as completing reports or working on code. Short lower mental workload tasks were either tasks that did not need much focus, or were distinctly different activities like watering plants. Comparatively, longer low mental workload tasks involved reading and processing large amounts of unimportant email.

3.2 Good and bad Mental Workload

Another often held but false assumption is that high mental workload is what we are trying to avoid, or is bad. Our prior work [7] highlighted that people found that high mental workload was required to achieve difficult tasks and to be successful, and in these respects was good. The data in Table 3 is designed to highlight good and bad mental workload at different levels to provide a grounding to this prior finding.

Participants enjoyed some forms of low mental workload, qualifying how they felt about the tasks with statements like *"I worked well while I was supposed to and now I'm going to have a well deserved break"* and *"Finishing off for the day, relaxed"*. When participants were not happy with having a low level of mental workload, they gave explanations to the bot such as *"Unhappy with mental workload, because I am not working enough"* and *"It is a waste of time"*. This gives some support to the premise in the mental workload cycle that people did not want to be stuck at a lower level.

There were times when high pressure were the reasons given for high mental workload being bad, such as *"Rushing before my lecture. don't have enough time."*, but to support the findings of the mental workload cycle, we saw some reasons such as *"Deadline fast approaching, need to grind all day"*, where participants had no option to be at a lower level due to their work demands. Yet we also saw plenty of examples where high mental workload was good, for both work (e.g. *"It is a lot of good information"*) and play (e.g. *"High intensity of playing against other players"*) situations.

Medium workload tasks also had a mixed response between participants being pleased and unhappy. Some were *"Enjoyable and relaxing"*, and clearly had an increased, but not high, mental

	Short tasks	Medium tasks	Long tasks
High MWL	- Plan priorities for the week - React app build - Email Management - Submit coursework - Push up code - Review CVs - Refine Survey - Dissertation work: draft consent form email - Project discussion - Experiment check	- Email Management - Clear all emails - Grievance Follow Up - Test DNS - Work on Discussion - Review Prototype - Dissertation work: film video for testing - Dissertation: finalise user testing - Database coursework - Complete annotations for storyboard	- Complete end of year performance review - Training session - Prepare presentation - Improve reliability of Apple Health integration - Work on dissertation - Gym - Complete storyboard - Revise notes
Medium MWL	- Fix bug with component - Timeout bug - Buddy Catchup - Update Survey Screenshots - Review Timelines for the week - Sign off Recruitment - Get all-time data to share on LinkedIn - finish off AI coursework - Attend standup	- Catch up with team to discuss missed sprint planning - Creating hand over docs for holiday - Prepare demo - Prepare for review - Read 1 chapter of book - Goals writing - Go grocery shopping - Add screenshots to Note taking sheet - Python training	- Refactoring Code Base - Prepare for demo and ppt - Add all missing invoices - gym - Emails - Catch-up on Games Content + Lectures
Low MWL	- Check emails - Grab lunch - Media Services Search - water plant - Jury Service - YouTube/games - Format and produce overall CW document - Clean room	- Go for a walk - Other areas of business including checking emails - Cook dinner - Clean up room - Attend meetings with teammates - Laundry - Reply to messages on Intercom - Update DNS code after review - social media/games	- Read 1.5 chapters of book - Catch Up on emails - Big data

Figure 2: Task length and MWL

workload: *"I'm finding it a bit more challenging but I'm still finding it fun to do"*. As per the mental workload cycle, people did report being bored of being stuck at a medium mental workload level, saying *"I've been doing this forever"*, however sometimes people gave a response based on their capability to do the work even if only involving a medium level of mental workload: *"I'm struggling with understanding some content"*.

4 DISCUSSION AND CONCLUSIONS

For time planning and time management research, our study produced lots of examples of short tasks and long tasks at every level that could be organised into a cycle. Our prior research indicated that people feel better when they can cycle between high and low mental workload throughout the day, and have negative experiences when they are stuck in a cycle. This research produced examples

	Unhappy	Neutral	Pleased
High MWL	- Dealing with a complaint - Basketball game - Proof reading a 2000 word essay coursework. - Working on storyboarding for a coursework. - Working on a commission. - Writing my dissertation. - Finishing coursework. - In a meeting. - Taking maths notes, during an online lecture. - Revising for an exam tomorrow.	- Watching a lecture - Essay work - A university test - Applying for jobs - Still writing dissertation - Writing my essay - Sorting out a freelance job - Coursework with team mates - Still working on C++ programming coursework - Doing coursework and getting distracted with a video game updated video.	- Playing chess - Submitting a paper - Programming a website - Jogging - Reading a book - Doing documentation for programming coursework - laser tag - Giving a presentation - Computer graphics coursework - Listening to a lecture
Medium MWL	- Getting out of bed - Working on coursework - Dissertation research - Going over maths lecture - Relaxing and doing some team work - Collecting sources for my literature report - Trying to fix a bug in an unfamiliar code base	- Research task - Playing a video game whilst watching a YouTube video - Refactoring a code base - In a meeting - Taking notes in a lecture - doing exercise in python to create derived classes - I'm programming a website - Watching a video on react hooks - Watching lecture on schizophrenia - Taking a break, playing guitar	- Preparing for a meeting - 2nd year group meeting - Extracting DNA from bacterial cells - Adding a progress bar to a website I'm making - Graphics coursework - Cleaning - Playing games - Writing code for my C++ Coursework - Preparing notes for the day - Taking a break for lunch - Relaxing
Low MWL	- Doing my hazard perception - I was in a meeting - Chatting with friend - Resting - Nothing - watching a lecture on summer exams - Sleeping - Queuing for coffee - Getting distracted - Doing my hazard perception	- Walking home - Watching YouTube - Having a nap - Still doing my driving theory test - working on my computer security lab - Putting up posters - Preparing lunch - Cleaning my room and preparing for my interview - Doing laundry - Shopping	- Watching TV - Finishing off Python course for the day - Taking a break - Eating - Having coffee with friends - Relaxing - Going to town - Listening to music - Playing video games - Cooking lunch

Figure 3: Mood and MWL

of tasks and activities by size, and by whether they good or bad in people's experiences. Future work could study ways to help people create a MWL cycle for their day, or to evaluate their day in terms of a cycle, to see whether good or bad cycles notably affect their lives. Such research would need to be longitudinal to understand how people feel better over time, and to understand when people can and cannot influence these cycles.

Within the work we saw lots of good or fun high mental workload and lots of bad low mental workload. This is interesting because the default mode in research is always to avoid high mental workload or help people reduce it. Yet there was lots of times when people reported that they felt like they were wasting time or being prevented from changing level in the cycle. Our next stage of research is to analyse the interviews to understand more about how people felt about mental workload and how they managed our day, and reflect further on the mental workload cycle. We expect

to publish results from a complete analysis of these two studies in our future work. In our future work, we then plan to design ways to help people track and reflect on mental workload as a concept and on their mental workload cycles [9], to see how it may play a role in future cognitive personal informatics.

REFERENCES

[1] Adrian Aguilera and Frederick Muench. 2012. There's an app for that: information technology applications for cognitive behavioral practitioners. *The Behavior therapist/AABT* 35, 4 (2012), 65.

[2] Fatema Akbar, Ayse Elvan Bayraktaroglu, Pradeep Buddharaju, Dennis Rodrigo Da Cunha Silva, Ge Gao, Ted Grover, Ricardo Gutierrez-Osuna, Nathan Cooper Jones, Gloria Mark, Ioannis Pavlidis, et al. 2019. Email makes you sweat: Examining email interruptions and stress using thermal imaging. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–14.

[3] Norah H Alsuraykh, Max L Wilson, Paul Tennent, and Sarah Sharples. 2019. How stress and mental workload are connected. In *Proceedings of the 13th EAI International Conference on Pervasive Computing Technologies for Healthcare*. 371–376.

[4] Ian Li, Anind Dey, and Jodi Forlizzi. 2010. A stage-based model of personal informatics systems. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 557–566.

[5] Luca Longo. 2018. Experienced mental workload, perception of usability, their interaction and impact on task performance. *PloS one* 13, 8 (2018), e0199661.

[6] Serena Midha, Max L Wilson, and Sarah Sharples. 2022. Ethical Concerns and Perceptions of Consumer Neurotechnology from Lived Experiences of Mental Workload Tracking. In *2022 ACM Conference on Fairness, Accountability, and Transparency*. 564–573.

[7] Serena Midha, Max L Wilson, and Sarah Sharples. 2022. Lived Experiences of Mental Workload in Everyday Life. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–16.

[8] Alexander Seifert, Anna Schlomann, Christian Rietz, and Hans Rudolf Schelling. 2017. The use of mobile devices for physical activity tracking in older adults' everyday life. *Digital health* 3 (2017), 2055207617740088.

[9] Jwan Shaban, Max L Wilson, and Sarah Sharples. 2023. Designing for Reflection on our Daily Mental Workload. (2023).

[10] Sarah Sharples. 2019. Workload II: A future paradigm for analysis and measurement. In *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018)*. Springer, 489–498.

[11] Katarzyna Stawarz, Anna L Cox, and Ann Blandford. 2015. Beyond self-tracking and reminders: designing smartphone apps that support habit formation. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems*. 2653–2662.

[12] Niels Van Berkel, Denzil Ferreira, and Vassilis Kostakos. 2017. The experience sampling method on mobile devices. *ACM Computing Surveys (CSUR)* 50, 6 (2017), 1–40.

[13] Christopher D Wickens. 1979. Measures of workload, stress and secondary tasks. *Mental workload: Its theory and measurement* (1979), 79–99.

[14] Max L. Wilson, Serena Midha, Horia Maior, Lewis Chang, Anna Cox, and Lachlan Urquhart. 2022. Moving from brain-computer interfaces to personal cognitive informatics. In *Proceedings of ACM SIGCHI 2022*. ACM Press.