Designing Apps to Track Mental Workload

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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 (CogPI) has become a pressing issue. In this paper, we present a series of recent design ideas our students have produced focusing on representing the notion of Mental Workload (MWL) to participants as something that future technology might track. While some notions of CogPI will have been considered for e.g. mood and stress tracking, our designs have been built specifically in relation to design metaphors that our prior work have identified as being relevant to MWL.

CCS CONCEPTS

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

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1 INTRODUCTION

An imminent future is that consumer neurotechnology is arriving en masse, and in many ways we are not ready to benefit from them. In relation to tracking cognitive activity like we track our physical activity [8], we do not know what counts as good cognitive activity levels, how people conceptualise cognitive activity, and how data about cognitive activity should be visualised to people, what they would think about it [5], nor what ethical concerns there are about this kind of data [3].

We argue that a trackable [2] type of cognitive personal informatics is mental workload (MWL) [6], which as opposed to e.g. stress [1, 7], is emotionally agnostic in that it does not imply a certain level is bad. In our recent work, studying how people experience and understand Mental Workload [4], we proposed that people manage their day according to a cycle - a good balance of high mental workload and low mental workload throughout the day makes people feel like they have achieved things and have taken breaks from being overworked.

An open challenge, in this regard, is to think about how to visualise different types of day to participants in terms of how mental workload has varied across the day [5]. The aim of this paper is to share some of the more recent design ideas that have come from a mixture of projects since our earlier work [9].

2 SOURCES OF DESIGN IDEAS

The ideas presented in this paper have come from two recent student projects, one which is based upon some design ideas from a past interview study, and one that is the product of a set of three design workshops.

2.1 Reflections from an Interview Study

In our past work, we interviewed 19 people that had previously spent 5 days rating their mental workload every 30 minutes [4]. During these interviews, some conceptualisations and design issues were discussed, and we concluded that there were four factors to balance in terms of design: intensity, sustainability, balance, and capacity[1]. We consider some of these aspects in our various design ideas below.

2.2 Participants in a Workshop

During a subsequent project, we held three co-design workshops of 5-7 people each. The first two co-design workshops had different types of participants by educational discipline: 1) science, 2) education and 3) business. Participants were given descriptions of MWL and examples of good and bad, high and low MWL in different situations. As a sensitising activity, they were asked to provide their own examples of MWL to the group. For the remainder of the two hours, participants sketched designs. The third workshop had a mix of participants and rather than creating new designs, they began by reflecting on the outputs of the prior two workshops and focused on selecting and refining the best designs.

3 DESIGN CONCEPTS

In all cases of design in this project, we have avoided using the traffic-light colour system to imply that a level of mental workload is bad, as low and high mental workload can be good and bad depending on the context. High mental workload during gaming, for example, may be experienced positively.

[1] these are described further in a publication that is under review

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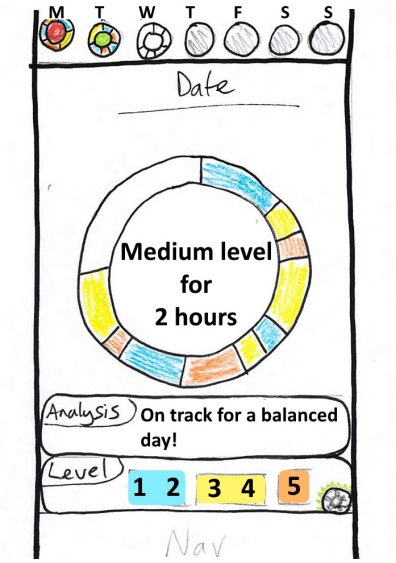
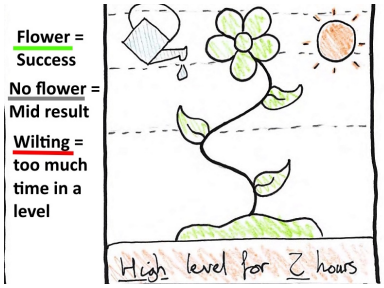
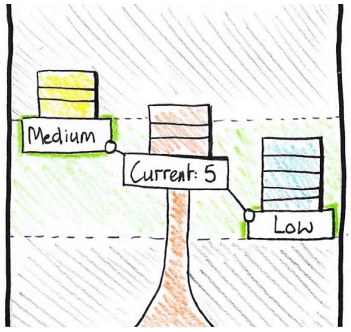


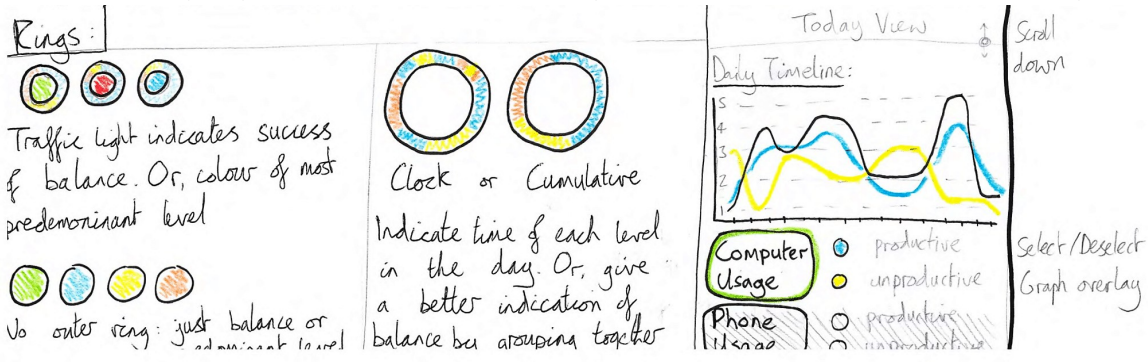
(a) Ring design



(b) Plant design - alternative mid-section



(c) Balance design - alternative mid-section



(d) Additional configurations shows options for showing if a day is good or bad in the history view, options for ring, and relationship to other types of data about computer usage.

Figure 1: Interview Design Outputs

3.1 Interviews: Plant Design

The Figure 1b design poses daily mental workload as a garden to tend, where spending time in different levels of mental workload enacts various cultivation activities - in this case low level is represented by watering, and high level by sunlight. Over the course of a day the plant responds to the 'gardening' and grows differently depending on water or sun. More water makes it grow vertically, and more sun adds flowers. An even amount of each activity achieves *balance* and the plant grows tall with many flowers. By tying mental workload to perceivable results, this idea takes a gamification approach to the mental workload cycle identified by Midha et al. Conscious consideration of mental workload level is encouraged in order to achieve the optimal result (growing a flower). *Sustainability*, and the negative effects of continuing on one level of mental workload for too long could be represented by wilting in different ways. Too much sun and the flowers may dry out, too much water and the plant is flooded or sags. Naturally, too, a tall plant with now flowers indicates a day was largely low mental workload, but a day with a short plant and only one flower would indicate a high mental workload day. Combined, a historical view would show the final state of the plants for each day. It is less clear how *intensity* is portrayed. While it could be showed in its current state for more water coming from a watering can, or more beams of sunlight, this would be lost as viewed retrospectively.

3.2 Interviews: Balance Design

Taking the concept of *balance* more literally, Figure 1c design focuses on where segments of Mental Workload weigh down a set of scales. In the sketched design, segments are placed in the scale that is currently central, which always represents the current level of Mental Workload. When the current level changes, the cups swap places, showing that someone could move to one of the other levels to add balance. Filling all 3 scales equally, and keeping the scales in

the green zone indicates a successfully balanced day. Larger segments indicate longer time periods, and more segments filling the scales over the course of a day conveys *capacity* as a visible weight is carried. In discussions with participants, the moving central item of the scale, and indeed balancing three items on a set of scales, were all aspects of the design that people found hard to ratify. An alternative view of balance could be a sand visualisation, where the sand pouring point moves between cups that can be filled, such that a balanced day is when the cups are evenly filled, and capacity is still represented by all cups being within a green zone, showing that all have been filled to some extent, and none filled too far. *Intensity* and the *Sustainability* of being in mental workload levels are not so clearly visualised.

3.3 Interviews: Ring Design

The Figure 1a design draws from popularised physical fitness tracking apps, but with some changes to match the features of cognitive activity. Instead of a quantity based target, the ring designates a the space of a day, and highlights *capacity*, filling in like a clock face. Colour coded segments of time represent the *intensity* of the different levels: Low, Medium, High. The ring then shows how much of the day is spent at different levels. At the end of the day, the coloured segments are collected together to show the overall distribution and *balance* between the levels. Balance could be inferred from the spread of colour (which is not directly related to traffic lights, since high does not mean bad), however an alternative option is to show a cumulative portion of the ring for each level (see the middle of Figure 1d) rather than a time-literal representation, so it easier to determine if a desired balance has been achieved. *Sustainability* could be represented by a the colour of a portion of the ring degrading in colour intensity as more time is spent at that level.

In a historical view, the centre of the circle could represent the day as a whole, where options are showing in Figure 1d on the left. We considered two options: 1) if there is a predominant colour, the centre circle fills in with this colour, showing that that day was e.g. a high mental workload day. It may be that people always have the same majority though, and so an alternative centre-circle scheme could show green if a good or desired balance is achieved.

3.4 Interviews: Brain Icon Design

The aim of the brain icon design, shown in Figure 2, was specifically aimed at moving away from colour implying a linear scale of *intensity*, especially to remove the idea of the traffic light system implying that high mental workload is bad. In practice, our research has shown that all levels of MWL can be good and bad depending on the situation [4]. In this case, we selected images of brains with added expressions that match different MWL situations. A historic view would show the most relevant brain icon to the majority of the day. The *balance* of each level is represented by three colour circles, which grow proportionately to each other as the day is balanced. Taking this icon-based approach, however, the app does not directly consider design ideas behind *sustainability or capacity*. The brain icon design proposed ways to tie in other forms of data that Midha et al considered, such as sleep, food cravings, and device usage, to help users identify patterns and associations.

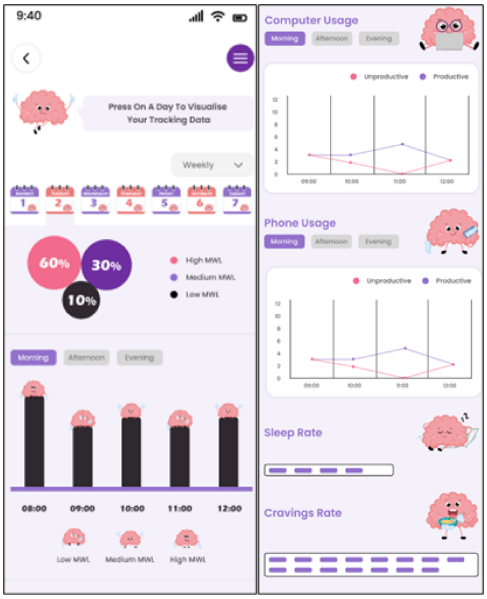


Figure 2: Icon-based design concept from interviews.

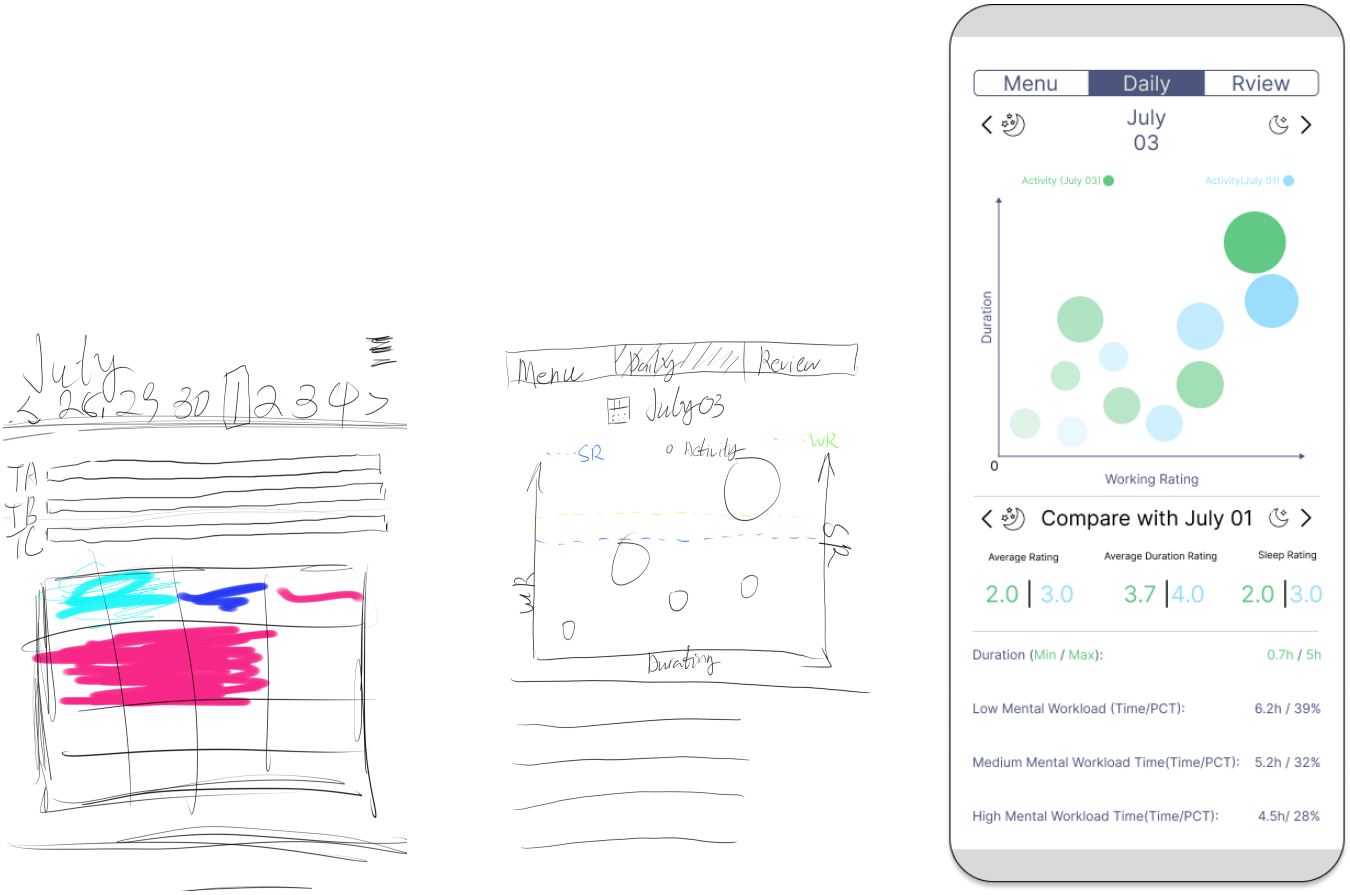
3.5 Workshop: Grid design

Figure 3a shows presents a novel attempt at data visualization. Inspired by the insights from the first workshop, this approach aims to visualize data by partitioning the time dimension into equal segments. The meaning of each block varies for different time spans. When on a daily basis, each block represents an hour, totalling 24 blocks in the chart. When displayed on a weekly or monthly basis, each unit corresponds to a day, resulting in a total of 31 units. Three distinct colours are employed to represent three different levels of mental workload. The area formed by these different coloured blocks conveys the duration; larger blocks represent longer durations and vice versa.

Although this approach was deemed highly innovative by workshop participants, it encounters limitations such as the inability to accurately depict workload levels (rating from 1 to 5) and the inappropriate choice of colours, which can lead to confusion for users trying to interpret the content.

3.6 Workshop: Bubble Design

Figure 3b and Figure 3c show a design idea where periods of mental workload are represented by a bubble, where length and level of mental workload make a 2D space. Large bubbles to the right mean long periods of high mental workload. Small bubbles would be small time periods, and if to the left would mean they are low mental workload. Colour intensity is also tied to horizontal position to emphasis *intensity*. With these in mind, *balance* would come from having the space evenly filled. Having a space-filling layout, with items bouncing around each other (rather than overlapping), the 2D space highlights a sense of *capacity*. One unsolved aspect of this design, however, is whether it still makes sense for two bubbles that should occupy the same space, actually sit next to each other even if this is not directly related vertically to e.g. the exact duration.



(a) Initial grid-based design **(b) Initial bubble space design** **(c) Developed bubble space design**

Figure 3: Workshop Design Outputs

In the more developed design (Figure 3c), we also highlight sleep scores on the night before and night after as a form of context. Figure 3c actually shows a comparison between two different days. As the bubbles shrink accordingly, the capacity of the 2D space should represent the total space for two days. Such a visualisation could then be used to show different spans of time, as long as the size of bubbles change in relation to proportional capacity for that number of days.

4 CONCLUSIONS

Our design work so far has come from a mixture of projects that are considering based upon the results of prior studies. The aim of our future work is to consolidate our design ideas into a series of design options that can be built into more interactive prototypes and evaluated in practice with people tracking their mental workload. A challenge for this work is that the technology to automatically track these things with sensors is not yet ready or easily deployable with participants. When there, a challenge will be to translate measureable data to these concepts we believe will be meaningful for non-expert users.

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