Are You Sitting Down? Towards Cognitive Performance Informed Design

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With many digital interaction designs, we can choose to operate the devices from a variety of postures – what we call self-positioning. In this paper we test two of these choices – sitting vs standing against standard neuropsychological assessments of cognitive executive function. We show that such choices do have significant effects on various cognitive processes. We argue therefore that there is an opportunity to extend parameters of digital interaction design to include self-position in order to optimize that design's effectiveness for its intended activity.

Design, Cognitive Performance, Self-Position, Sitting, Standing, Pre Frontal Cortex, Cognitive Executive Function.

1. INTRODUCTION

In HCI we have been keenly interested in improving task performance based on interface widget designs that can improve target acquisition, reduce number of steps taken for task completion and where successful completion of a task may be measured against not only error free process, but experience of positive affect (Dillon 2001) as well. Within these metrics, beyond occasionally considering how well we might physically move our bodies while performing a task on the go and not walking into a tree (Wilson et al. 2006) we have rarely considered how our cognitive interactions may be affected by the body, by the brain doing its cognitive work as part of a body-brain system. There is more going on than that the brain moves the finger that touches the screen: the physical state of the body influences the responses of the brain that then may affect not just task performance, but whether and how well the task is engaged at all.

In HCI it seems we have not well explored even how something as simple as our physical self-positioning (standing, sitting, lying down) may impact not just on the physical ability/comfort to perform a task (yes I can reach this keyboard and see that screen) but on how well we might optimally be able to perform them. What if insight will always come in the shower while moving the body - soaping oneself - but the breakthrough calculation will only ever happen sitting down still, leaning forward? The implications of such positional-cognitive affordances and constraints for design becomes immediately apparent: without such understanding, we cannot know whether we are designing effectively to support optimal opportunities for instance for creativity, innovation and discovery.

Human Factors (HF) research, one may say the root of what would become HCI, has certainly been concerned with physical effects on human performance. Key texts in HF (Wickens et al. 2004) (Wickens and Hollands 1999) demonstrate concern about measuring stress on humans in particular situations and considering re-design in those fixed contexts – like display organization within the constraints of a cockpit – to improve well defined task performances like start the engine; monitor flight path. Here the body and brain seem largely to be another system that must be worked around with its soggy performance constraints in order to make another system (like a cockpit or surgical theatre) work better. If we step outside the cockpit and into blue sky as it were (defying gravity as well), our goals may be seemingly less task-definable. We might ask how do we best design our interactions with information systems – and their environments - to enable us to be more creative, more insightful, in our work? In particular, the question we wish to explore is that, since there is a body-brain interaction, how might the body's effect be taken into account in such designs?

Work situated as "embodied interaction" (Dourish 2001) may be seen as the first step in HCI to take the body out of task-based HF design constraints. It suggests that there is not only design value but important social implications in considering that we are both physically present as part of social systems, and physical beings who can do more with our hands and eyes than push keys and read charts. Designers and theorists in the space have pushed on leveraging these often implicit attributes (Chalmers and Galani 2004) of physicality and presence for design exploration.

In this paper we propose a potential joining of human factors informed knowledge of cognitive performance with embodied interaction values in order to explore a more particular aspect of the embodied being, one that, at least initially, is less phenomenological and more neurological to better understand how the body may contribute to improving traditional and novel interaction designs.

As a starting point on crafting this map of the body-brain dynamic, we wish to understand how self-kinetic performance – how self-position and self-movement - affects cognitive performance. Related work in cognitive neuroscience (Ratey and Loehr 2011) shows us that regularly physically active people perform better on cognitive tests. Our question for design in regarding body-brain interaction is, may the effects of the body be more subtle and immediate than those wrought by persistent working out or by a sudden attack of the flu. We wish to explore if and how the current state of the body *immediately* affects the brain's performance. If such affects are immediate and traceable making them available for exploration, then it seems fundamental if not critical to explore how we might leverage this interplay deliberately in our artefact design to better enhance our performance.

1.1 Motivation

Our motivation informing this work is at least two fold. First, we are stirred by the potential for specific brain measures to inform constraints and affordances for both design and its evaluation for novel interactions particularly designed to support creativity, innovation and discovery.

Second, we see a pragmatic and immediate value in developing such understanding to inform existing designs. When we are, it seems, daily closer to what is imagined as a ubiquitous experience of wall-sized displays on the one hand, and interactive table top surfaces on the other, where walking and standing desks are being proposed as solutions to a host of evils from obesity to stress (Levine and Miller 2007a) understanding what *kinds* of cognitive tasks these devices might optimally support when they so deliberately if implicitly insist on a particular body position seems useful information for HCI designers and researchers to have.

Are we sitting down when it is best to sit; standing or walking when best to stand or walk? If our design goals might be more efficient use not just of our time, but of our brain's limited performance cycles, how to design to take advantage of those precious cycles seems fundamental to improving our quality of (work) life (Rapley 2003). If we can find ways to work not only more efficiently but more delightedly, and design to gain insight faster and more fully by an awareness of the body-brain state in these embodied interactions then, quality of life (QoL) may improve Improved QoL was also the failed promise of the paperless office. When the design goal is to improve QoL directly, rather than have that as a consequence, our chances of achieving it may be improved.

In this paper, therefore, we present a start to this exploration of the effects of physical self-positioning on cognitive task performance. We present the background to, and the design and results of an experimental study simply to test whether sitting or standing has a significant effect on cognitive performance, and if so on what kinds of cognitive tasks. We see that position does have a role in cognitive performance. We conclude by looking at the immediate design implications from these findings, we propose the start of a research agenda for kinetic interaction as directions for future work.

2. RELATED WORK

In this section, we consider related work from two domains. First we overview a few key examples of related work in HCI. Second, we summarize informing concepts and findings in cognitive neuroscience and human performance as they inform our experimental approach. These two areas may seem rather disparate, but they are both strongly related as mutually informing the questions we propose to explore.

2. 1 Related Interaction Work.

As noted above, Human Factors is often the first place HCI researchers may turn to understand the constraints on design imposed by the particular perceptual limitations of the brain and the related response times of the body. These constraints are then used to help reduce effects of stress, for instance, in cognitively taxing environments from nuclear control rooms (Vicente 2004) to medical ward performance (Thimbleby 2010)

The related field of visualization may be said to be largely informed by cognitive color perception for sense making and saliency detection for highlighting important attributes (a red circle in a sea of blue circles). Just these attributes show the importance of understanding how the cognitive-physical performance of vision affects our perception (Ware 2000). Likewise, the ubiquitous Fitts's Law, the single most cited equation in HCI, demonstrates the concern in our discipline to mitigate motor learning performance drag on the cognitive task performance of target acquisition. For example, expanding target size is one solution to enable grosser, faster motor movements that require less trained dexterity to acquire a target (McGuffin and Balakrishnan 2005).

From looking at mitigating the constraints and leveraging the affordances of our sensory-motor systems, Embodied Interaction (Dourish 2001) draws on more phenomenology than psychology for design. On the one hand it asks what does it mean *for* interaction design to take advantage of our *physically* being *within* social systems (MacColl et al. 2002) On the other it considers how attributes of artefact design might engage us through our physical senses. Here, physical affordances are merged with digital properties deliberately for tangible interaction. Whether something is fur or wood, heavy or light – connects with the interaction by taking advantage again of our very physical/cognitive perceptual senses (Redström 2008), (Shaer 2009).

Here, design engages both social and tangible computing. In the tangible space, designers take advantage of what being in a body affords – we have two hands: we can pick things up; we can touch, feel pressure and heat; let us design to embrace these capabilities. With physical social computationally mediated interaction (Benford et al. 2005). we acknowledge that we exist as embodied beings in social systems, and these interactions inform communication and making meaning. So we can take design advantage of these attributes as well.

More recently design work coined "kinetic object interaction" (KOIs) (Parkes, Poupyrev, and Ishii 2008) uses motion –aural, tactile, kinaesthetic – of artefacts to enable both communication and reflection. For instance simple objects like pucks can be magnetically attached to a table where the strength of the attachment an thus ease of movement becomes a deliberate attribute of its state. In KOIs it seems that movement as a key part of organic (or living and dying) environments is a fundamental assumption about communication, and is thus a critical property for interaction.

There is also growing interest in how self-monitoring of physiological state may be used to help us adapt that state for better performance. There are significant questions around how to integrate that information and convey that useably for people. For instance, we know that slower deeper breathing can reduce stress symptoms that inhibit cognitive performance. Moraveji and colleagues (2011) looked at how a peripheral awareness UI could help people recover this more positive form of breathing effortlessly throughout the day. Here the authors leverage established knowledge around stress to translate that into helpful interaction designs. There are many opportunities here to connect such knowledge for performance support design.

In terms of the work we propose in this paper, we are asking more about unknown and untested attributes of the body-brain interaction in order to understand and scope how these interactions might inform our designs.

2.2 Related Work in Cognitive Performance

In the area of investigation we propose, we seek to understand if and how physical interactions from eye movement to body position may influence cognitive performance. Cognitive performance is itself a broad term with multiple attributes from recall to attention management. We therefore briefly touch on some of the attributes of the brain's role in cognitive function – at least what cognitive neuroscience research suggests it is today, as these views have changed significantly over the past 25 years. We will also highlight some associated studies in cognitive performance, brain function and physical position. This framing will set the stage for the study we report in this paper where our end goal will be to see how these findings may be applied initially to knowledge work.

Cognitive function largely involves the area of the brain known as the pre-frontal cortex (Figure 1)

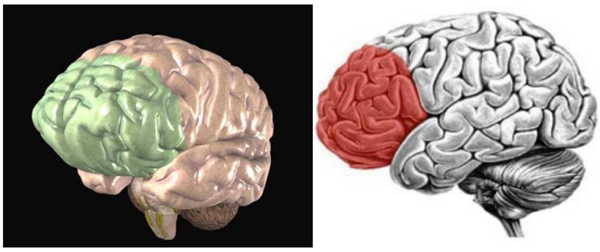

Figure 1 Pre Frontal Cortex area of the Brain

In particular, cognition is mainly involved with what is known as cognitive executive function (CEF). CEF is often used as an umbrella term for cognitive activities such as planning, working memory, attention, problem solving, verbal reasoning, multi-tasking, and monitoring of actions among others (Chan et al. 2008).

Our goal in this work is to understand the effect self-positioning may have on CEF. Fortunately there are numerous well-accepted ways to assess CEF performance. CEF tests are categorized as "neuropsychological assessments" and have mainly been developed as clinical measures to detect cognitive performance aberrations from the norm. They are also used to help develop treatment to reduce disease or condition effect. Conditions from ADHD to autism to effects of cancer on the brain are assessed and graded with these measures (Groth-Marnat 2009).

More recently, these same measures have been used to grade the impact of physical practice (or the lack of it) on cognitive performance in otherwise healthy individuals. A survey of this research can be found here (schraefel 2011). Two consistent findings have emerged from this body of work. First, people with a history of physical activity perform better on CEF assessments than those who have been sedentary. In fact people who remain sedentary progressively perform worse (Singh-Manoux et al. 2005) over time. Second, a dose of exercise, such as twenty minutes of light cardio effort on a stationary bike, regardless of age, ethnicity or gender, before a CEF assessment, improves test performance (Hillman et al. 2006; Eskes et al. 2010).

Of particular relevance to the work reported here is that in the past two years, there have been several studies looking at the difference between sitting and walking desks measured on a host of psycho-physical measures (Levine and Miller 2007b) and where various CEF tests have been used in particular. Intriguingly, while the trend seems to be that many attributes improve from standing (Ohlinger et al. 2011) or at least do not degrade, the positives are not clearly universal. One study showed that certain tasks performed at what are known as “walking desks” where one walks on a treadmill fixed to a standing desk, definitely performed more poorly(John et al. 2009). Likewise the papers do not all use CEF tests that study the same attributes of CEF. Some may focus on motor speed/motor control (Ohlinger et al. 2011) rather than Complex Attention or Cognitive Flexibility. While one might demonstrate that such a measure remains high for standing or sitting or walking at a desk, how important is that result to daily activity? It is important for designers to see to what kinds of actual tasks these results may map.

In our study design therefore, we wanted to look at CEF assessments with self-positioning that could more directly inform design of digital interaction. For instance, motor control may be important for gaming, but may not be a key factor for managing email. Other measures like attention and recall may be more important, or at least more descriptive for multi-tasking, a common element of most of our digital-physical lives. We are also interested in understanding the role of these various CEFs throughout a creative process from idea generation through to worked solution.

In the following section, we describe the experiment we designed to begin to assess a more design-oriented assessment of CEF performance and the effect of self-position upon that performance.

3. EXPERIMENT

Our experiment is to test how sitting and standing affect various components of cognitive executive functioning.

3.1 Hypotheses

Our first hypothesis was that self-position would have a significant effect on cognitive task performance. Based on related work in the use of standing desks, our second hypothesis was that standing would show better overall performance than sitting.

3.2 Method

Figure 2 participant setup, standing, sitting

To test these hypotheses, we ran a within-groups, counter-balanced study to test the effect of position on cognitive task performance using standard computer display/interaction technology. For this initial study we tested only seated and standing positions rather than mobile and reclined as well.

3.3 Participants

We constrained the participant group to men, ages 22-38 (mean age 29), all with science backgrounds and graduate degrees, and none of whom currently using standing desks; all participants worked in an open lab environment. Our rationale for the grouping was to reduce as many potential variables that might be said to influence within-group outcomes. In a computer science lab, the grouping represented the most common population. 17 men participated. Participants signed an information and consent form approved via the University’s of Southampton Ethical Review of Human Participant Studies process. (ID:1497) Participants received a gift voucher as part of their participation.

3.4 Apparatus

The room for the study was set up with a standard height table and chair for the seated position, and boxes on the table for the standing condition (**Error! Reference source not found.**). The same laptop, a Lenovo Thinkpad T41p running Windows XP, was used in each condition. For seated, the laptop was placed on the table; for standing, the laptop was placed on the rigid boxes at an appropriate ergonomic height for standing work.

3.5 Test Battery

We used the CNS Vital Signs (CNSVS) test battery for assessing neurocognitive function. The included subtests were the following: Symbol Digit Coding test (SDC), Shifting Attention Test (SAT), Finger Tapping Test (FTT), Stroop test (ST) and Continuous Performance Test (CPT) in that order. We describe these measures in detail below. The tests themselves are online versions of standard measures of cognitive task performance. For our purposes in particular, a key value of this test battery is its established test/retest validity. This means that we can remove learning effect from consideration of the tests used, and we can also run consecutive tests without having to wait for days or weeks as some cognitive tests require. Counter-balancing exposure to the sit-stand test condition therefore was effectively a belt and suspenders approach to eliminate learning effect as an outcome factor. The test runs are also highly consistently delivered: the test battery is automatically presented to the participants with practice followed by test runs of each test in the selected battery.

The CNSVS test battery has previously been thoroughly described and tested for reliability by Gualtieri & Johnson (2006). In short, the subtests used in the present study provide domain measures of: Executive Function (EF), Complex Attention (CA), Cognitive Flexibility (CF), Psychomotor Speed (PMS), Reaction Time (RT) and Processing Speed (PS). The score of each of the domains are calculated either as differences between correct and erroneous responses within each subtest, or summation of the responses from two or more subtests.

The CNSVS standard scores and percentile ranks are auto-scored using an algorithm based on a normative data set of more than 1900 participants, ranging from ages 8 – 90. In the age-matched normative sample participants were: (i) in good health, (ii) had no past or present psychiatric or neurological disorders, head injury, or learning disabilities, and (iii) were free of any centrally acting medications Gualtieri & Johnson (2006).

The standard score calculation for each domain is summarized in Table 1. Below we list the specific assessments deployed in this study and how they are scored.

3.5.1 Executive Function Domains Tested

Briefly, Executive Function is a group of mental processes that helps connect past experience with present action. Activities such as planning and organizing, strategizing, paying attention to detail, memory formation and keeping track of time are all executive functioning tasks. The domain score of Executive Function is calculated based on the difference between correct and erroneous responses in the Shifting Attention Test (SAT) (Table 1).

The Shifting Attention Test (SAT) measures the participant's ability to shift from one instruction set to another quickly and accurately. This is done by continuously having the participant match either color OR shape to the displayed color-shape reference on the screen.

3.5.1.2 Complex Attention

"Complex Attention" is a domain score calculated on the numbers of errors made in three of the sub-tests. The three sub-test are: The Stroop Test (ST), the Shifting Attention Test (SAT) and the Continuous Performance Test (CPT). The number of errors made in each of the three sub-tests is added together to provide the total score of "Complex Attention" (Table 1). Examples of complex attention include the ability to keep a sustained focus, to resist distraction as well as information processing ability. This form of mental flexibility could for instance be exemplified by hearing a list of digits/letters and putting them in numerical/alphabetical order.

The Stroop Test (ST) is a test on selective attention. Selective attention is required in tasks that involve the inhibition of competing responses. During the ST participants are required to name either the color of the ink in which a word of a color is written or name the word itself. When word and color do not match interference arises, as the participant cannot stop reading the word. The interference manifests itself by an increase in response time. The ST together with the SAT, as described above, and the CPT, which is a test of sustained attention or focus provides the standard score of the domain Complex Attention. In the CPT, participants are required, for 5 min. continuously, to indicate when a pre-defined letter appears on screen.

3.5.1.3 Cognitive Flexibility

Cognitive flexibility describes the ability of central command to switch behavioural responses according to the situation. For instance, strategic planning and organized searching utilizing environmental feedback Cognitive Flexibility allows for a 3D attention shift without loosing focus. It is very much linked to Executive Function performance and therefore also based on the SAT with the addition of ST [errors] in the standard score calculation. The ST provides a selective attention element to the Cognitive Flexibility score where inhibition of competing responses is necessary to choose appropriate behavioural responses. An example of Cognitive Flexibility includes the ability to sort an array of information in a predefined sequence.

3.5.1.4 Psychomotor Speed

Psychomotor Speed is the ability to think and do something fast. The domain is comprised of the Finger Tapping Test (the motor-part) and the Single Digit Coding test (psycho-part). The Finger Tapping Test is simply a test to see how fast one can perform a simple motor task. In the FTT the participant taps the SPACE-bar on a computer keyboard as many times as possible for 10 sec. for three trials with right and left index finger separately. The score is then added to the SDC [correct] responses. The SDC test requires the participant to not only be quick moving but also quick thinking by matching a symbol (decoding information) with a number and then typing that number (movement execution).

3.5.1.5 Reaction Time

The Reaction Time domain score in the CNSVS test battery is a combination of simple and complex reaction time. Simple reaction time is generally defined as the ability to respond fast to a stimulus with no interpretation required. For instance, as in the first part of the ST the participant was required to respond by finger tap on the SPACE-bar as soon as a word of a colour written in ANY colour appeared on the screen. In this case no interpretation was required just a response to the stimulus. Conversely, Complex reaction time is the ability to rapidly decode the stimulus and then respond appropriately. For instance, in the second part of the ST, the instructions to only press the SPACE-bar when the word and colour did NOT match (e.g. the word RED written with the colour yellow) was given. An average of the correct responses from simple and complex reaction time tests provide the domain standard score of Reaction Time.

3.5.1.6 Processing Speed

The Processing Speed domain standard score is based on the difference between the correct and erroneous responses in the SDC test. As mentioned previously, the SDC test required the participant to match a symbol with a number and then typing that number. “Thinking time” is the kind of attention required to successfully capture information, process it and respond appropriately. It is a cognitive function that influences the ability to comprehend lengthy, detailed and fast instructions or engage in conversations without loosing attention.

3.6 Protocol

Participants were greeted by an investigator who, with the participant, went through the material in the informed consent document, including how the study would be conducted, and what was being assessed. Any questions were also addressed here, with the opportunity to address any further questions that arose at the end of the study. Another investigator then ran the apparatus. The same investigator ran each introduction and the same investigator ran each participant trial.

Participants then began each condition by lying down for ten minutes. This rest period is a standard approach (Hayano et al. 1991) to bring heart rate (HR) and heart rate variability (HRV) levels to resting state and to have the most consistent physical start to each test condition. Influencing factors like racing up the stairs to get to the study room, or to lower the heart again after any elevation caused by the initial test block (George et al. 1989) Resting for ten minutes prior each test condition commencement and thereby re-setting vagal tone could be achieved. The participants were left on their own during the rest period.

Participants were randomly assigned to a seated first or standing first condition. We ended up with 8 standing first and 9 sitting first with one sitting test spoiled, so evenly matched sitting and standing starts.

Participants were shown how to start the tests on the laptop when they were ready to begin; the program guided them through each test, and indicated completion. Between test conditions, the laptop was repositioned for the next condition.

The total test time including rest took on average an hour and ten minutes.

4. RESULTS

The overall results showed that, for Complex Attention, seated performance was significantly better than standing [seated: 99+/-7.9; standing: 94+/-8.1; p=0.009]. In the other domains, no significant difference between conditions could be detected. Movement in percentile ranks was also significant in Complex Attention [seated: 49+/-19.1; standing: 36+/-18.2; p=0.008], which corresponds to a shift towards the lower end of the "average" or "normal" percentile.

We used a two-tailed Student's t-test with repeated measures to test for significant differences between the standing and seated condition. We chose this statistical test over the ANOVA since the main domains are calculated by adding several subtest scores together and thereby already have significant interaction between them (Gualtieri & Johnson 2006). An alpha level of <0.05 was considered significant unless otherwise specified and we report results as means +/- SD.

4.1 Hypotheses

Our first hypothesis on the significant effect of self-positioning on cognitive performance was proven. The results showed a significant statistical difference between conditions in the Complex Attention domain of cognitive performance. Our second hypothesis of the standing condition showing better results on cognitive performance was disproven. Complex Attention standard scores were significantly higher in the seated condition compared to the standing condition.

None of the other domains of cognitive performance were statistically different in the two conditions thus indicating that a subset of "global" cognitive performance is affected but not all aspects.

5. DISCUSSION

There are several take aways from this study. The first and perhaps most obvious is that self-position does have an effect on domains of cognitive performance. Of those domains tested, it's clear that for complex attention tasks, sitting is significantly better than standing. Perhaps equally interestingly, position does not affect the other tested domains of cognitive performance.

There are several questions that fall out of these results. First, for the significant differences in the complex attention domain, we must note that the difference overall still keeps performance within the same Normal Average percentile – it simply switches from the middle of the percentile (seated) to the lower end of the percentile (standing). This effect MAY be a significance without a particularly performative difference once applied to real world interactions.

Indeed, for both significant and non-significant results, for design we will need to understand how such tests that explore a single performance factor map to real-world interactions that will be more complex and nuanced. In other words, we have a rather abstract assessment in the CEF test battery. In terms of extrapolating conclusions about effect for real world interactions, the most we can say right now is that there is an effect, and that seems worth pursuing to see how this baseline abstraction around self-position and cognitive performance plays when applied to real world interactions.

For complex attention, for instance, where there was significant difference between sitting and standing, a possible mapping between assessment tasks and real activity may seen in game design that manages puzzle solving and pattern recognition. Mah Jong and Tetris, with their emphasis on recall and symbol manipulation may be better played sitting down. Similarly, carrying on an online conversation while organizing an attendee list for a conference, while keeping an eye on one's inbox may also be done better sitting down (if done at all). Working through a difficult part of a math proof may also benefit from being seated, rather than standing.

The math proof raises an interesting question, however. Many of us experience breakthroughs to problems when we are either going for a walk or shampooing our heads in the shower, and getting away from the seated, working memory focus of grinding away at the desk. Indeed there is an entire literature devoted to understanding what is actually formally called "the aha moment" (Kounios et al. 2006). In terms of our design goals to use self-position to support cognitive performance, we may ask, are there ways that we can help people identify the moments to shift self-position (going from seated work to mobile cogitation) sooner and thus accelerate pace of breakthroughs?

For the domains where we have non-significant differences between seating and standing, such as with psychomotor speed and reaction time, as well as with cognitive flexibility, we see no real differences in sitting or standing. That is, performing a motor task like target acquisition (pointer to icon) or manipulating a game controller or shifting attention from one's mail to one's tax return may not be affected by position. IF however we are shifting from an interaction like social network updates to doing the tax return, where we are drawing upon complex attention to manage symbols and make decisions, we may wish to move from standing to sitting.

An attribute of note within the results is that between standing and sitting in complex attention, there is only a narrow – but statistically significant movement within a percentile. The results move from the middle of the average percentile (sitting) to the lower average percentile (standing). The question may be to ask is whether this statistically significant difference will be masked or amplified in real world contexts, and if so, which ones?

For instance, there are more people blogging about how happy they are since they switched from seated to standing desks[1]. Anecdotally, we have also witnessed this in talking with people in organizations who have not had to pay for the desk change, so are presumably not motivated to approve an expensive choice. They speak of getting more work done, feeling better, and generally believing that they move more during the day, and that all these are positive effects. Do these perceived benefits outweigh the potential cognitive costs of standing when it might be better for a type of cognitive process to sit?

Indeed, physiologically, some human factors researchers in ergonomics have suggested that there are negatives to standing all day just as there are to sitting. They recommend changing position from seated to standing throughout the day (Hedge 2011) This council -- sit or stand anytime -- may be more random than necessary. Again, in terms of interaction design, it seems there is an opportunity to investigate how to reflect back to a person, based on what they are doing, for how long and perhaps in combination with other self-monitoring devices, when these self-position changes might best be undertaken.

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[1] http://jamieflinchbaugh.com/2010/09/the-stand-up-desk/

Effectively, our current study has suggested that we have more questions for understanding how the body-brain interaction may inform interaction design, that we have answers. We are hesitant at this stage to suggest Sitting is Better than Standing for Task X even as a heuristic, given the number of caveats about the study, addressed below. We do see that this early result is strong enough to warrant further investigation for the types of questions it has opened, as we have described here.

5.1 Limitations of Design

We customized the CNSVS test battery leaving out the Visual and Verbal Memory Tests (VIM and VBM, respectively). Gualtieri & Johnson (Gualtieri and Johnson 2006) showed high test-rest reliability of the complete CNSVS test battery as well as within the individual domains. However, due to our experimental design of running the two test conditions on the same day for each participant the VIM and VBM was excluded due to the short-term learning effect these might produce. For the same reason, as well as a time efficiency standpoint, we also excluded non-verbal reasoning and social acuity. Besides avoiding having a learning effect to take place, the underlying argumentation for excluding (non-verbal) social behaviour is found in the outcome measures of interest. The aforementioned subtests rely more on emotional perception than cognitive performance. While that is of great interest too, we decided to exclude those from this trial. Due to the high test-re-test reliability of each of the domain standard scores (Gualtieri & Johnson 2006) the customization of the CNSVS test battery is an appropriate adjustment to make whenever necessary as recommend by the creators of the CNSVS test battery[2].

In terms of position, we did not consider a particularly common style of working with laptops, which is reclining, a posture made geek-cultishly popular as *brogramming*.[3] Because two tests already take over an hour to complete, our goal has been to test more common work-place postures. Now that we have seen an effect especially on complex attention, we plan to test at least this CEF assessment in a reclined position. IF performance here is significantly better again than seated, such a result may have implications for workplace designs to new furniture.

Our study also only assessed men of a certain age, and no one who has been using a standing desk of any kind. We do not know, therefore, if there may be either a gender or a practice effect.

With respect to practice effect, standing does require more sensory-motor coordination (and so more energy) than sitting. We are running a pilot study to see if practiced desk-standers close the gap on the complex attention task, or if that task will always cause such a difference potentially because of this higher energy or attention demand for balance/vestibular coordination.

Finally, our study only looked at the course grained single factor tests for CEF. While the areas of the brain for CEF and creativity are apparently the same (Dietrich 2004), tests to assess creativity in particular are quite distinct from those just for CEF. It may be that standing, sitting, lounging, walking all have different effects on creativity assessments.

6. FUTURE WORK

In this initial study we have seen that for highly abstracted tasks designed to assess very specific areas of cognitive function, self-positioning has an effect on performance. In the discussion, above, we have postulated real world interactions where these findings may initially be applied and evaluated.

These tasks will still likely represent what we might call micro ecologically valid interactions for cognitive performance. The macro tasks – such as writing a paper – may involve far more fluid transitions between seated, standing, reclining, showering, walking self-positionings, all while still absorbed to varying degrees in a task.

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[2] http://www.cnsvs.com/index.php/faqs

[3] http://bostinno.com/2011/08/31/the-10-commandments-of-brogramming/

A future work challenge in which we are particularly interested is how we can both understand cognitive performance states, monitor these, reflect these back to people, and help them action choices to tune their performance. Another part of providing feedback is to understand where design itself may simply better facilitate consistently better cognitive performance for a given set of processes.

New kinds of pervasive and peripheral monitoring from heart (Mark, Voida, and Cardello 2012) to breath (Moraveji et al. 2011) to emotive state (McDuff et al. 2012) for instance, may blend with significantly different types of display that support an easy and effortless transition from sitting at a screen to standing at a wall.

7. CONCLUSION

This paper proposes a rationale of and offers experimental support for HCI designers and researchers to consider the inclusion of self-positioning as a component of interaction design. The paper offers three contributions for HCI research and design following from this position.

First, we show that self-positioning does have a significant effect on complex attention, a domain area of cognitive executive functioning that has particular resonance with knowledge working design.

Second we have shown other CEF domains like cognitive flexibility and processing speed, the effect of position is non-significant. The implications for design here have particular relevance for interaction designs from low level target acquisition tasks to global design like self-position for optimal game interaction for trigger firing.

Third, based on these initial results, we have shown that there is scope for further work in this area. To this end we have proposed a research agenda sketch in Future Work for further exploration of body-brain interaction for design.

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