KNOWLEDGE WORKER PRODUCTIVITY

MARCH 2013

RESEARCH THEME UPDATE

mediaX
STANFORD UNIVERSITY

mediaX at Stanford University connects businesses with Stanford University's world-renowned faculty to study new ways for people and technology to intersect.

We are the industry affiliate program to Stanford's H-STAR Institute. We help our members explore how the thoughtful use of technology can impact a range of fields, from entertainment to learning to commerce. Together, we're researching innovative ways for people to collaborate, communicate and interact with the information, products, and industries of tomorrow.

Incremental and Transformational Innovation for Measurable Improvements in Knowledge Worker Productivity

Research Theme Update

March, 2013

Acknowledgements

The research-in-process reported here is underway at Stanford University under sponsorship by a mediaX Themed Research initiative, made possible by a gift from mediaX strategic partner, Konica Minolta. This research initiative began with a question from the business community, and a small group conversation that grew to include an international business community and an interdisciplinary group of researchers. Building on a firm grounding in fundamental science from previous research, Stanford's world-class expertise has been brought to bear on a real-world challenge.

TABLE OF CONTENTS

Knowledge Worker Productivity: Incremental and Transformational Innovation for Measurable Improvements in Knowledge Worker Productivity Management

Introduction: Knowledge Worker Productivity

Incremental & Transformational Innovation for Measurable Improvements in Knowledge Worker Productivity

Knowledge is the fuel of technology-based organizations. And there is a difference if that fuel is used for waste heat or rapid acceleration. The corporate arena is competitive and has been continually reshaped by technological change. The Internet has leveled the playing field for access to information, and the innovation frontier has shifted to knowledge use and creativity. A serious productivity gap exists between available knowledge and how it is used. Like a hole in a bucket, a "knowledge gap" causes significant loss of resources and competitive advantage.

Managing knowledge workers is problematic. Many enterprises are not fully engaging the energy and intellect of the employees whom they compete to attract and retain. Corporations also don't fully harvest the benefits of the technologies they provide for those workers responsible for transforming knowledge into products and services. These underused technologies and human capital (used even modestly better) could reduce the productivity gap and accelerate growth dramatically. This creates an opportunity for organizations that can increase their productivity in capturing, processing, and using knowledge creatively.

This mediaX Research Theme Update provides a mid-year window into three ongoing Stanford projects, that have continued research initiated by mediaX in 2010. They began with a *question* on new metrics for knowledge worker productivity. Each project is unique to this theme, yet nests into other portfolios of research activities underway at Stanford and beyond. At its core, each project builds on prior research and is intended to serve as a foundation for future research. These three projects span organizational, team and individual levels of technologies (and processes) to enhance the "productivity of knowledge workers." The three projects that are updated here were initially launched in September 2011.

The Detecting States of Mind project (led by Jeremy Bailenson) seeks to identify data-driven indicators that can detect how well a group is "syncing" on a collaborative project. Using inexpensive commercial videogame platforms to assess non-verbal behavior, then using computational methods to predict collaborative innovation in learning and creative tasks, the team has developed a "thin slice" approach to non-verbal behavior data analysis. They are using this to examine face-to-face and online collaboration in dyads in order to help managers predict future success of creative work teams.

The Journey from Islands to Mutual Understanding project (co-led by Kincho Law and Renate Fruchter) is investigating the most important elements to create mutual understanding among team members in the context of collaborative decisions in creative global business meetings. With two use cases – a globally distributed class and a large organization – the team is implementing localizations of a prototype system. The system allows team members to build awareness of their individuals' local conditions, and make their local conditions transparent and visible to the rest of the team. The intended outcomes are feedback mechanisms and metrics that indicate the "engagement potential" of each team member and the team as a whole. It also provides feedback that nudges all towards alignment of expectations and synchronicity of engagement levels.

The Calming Technologies project (co-led by Roy Pea and Neema Moraveji) is devising and evaluating ways to technologically augment human self-regulation to help knowledge workers maintain an optimal psychophysiological state for "sustainable productivity." The team is developing and using a breathing sensor. The team is also collecting longitudinal respiration data, and qualitative data, to gather user feedback on annotation, comprehension and reflection of respiration patterns in work rhythms and productivity waves. These early insights are also being used in support of a longitudinal study on stress by UCSF. Evaluation of respiration and self-regulation continues.

These projects continue the mediaX **Knowledge Worker Productivity Research Theme** and its broad insight agenda on the question: *What insights about people and technology are needed to develop metrics than can be used to measurably increase the productivity to knowledge workers?*

Under the Knowledge Worker Productivity Research Theme, projects sponsored earlier by mediaX have provided a foundation of insights needed to transcend disciplinary approaches. They have also helped to increase and measure knowledge-based productivity gains. This is in response to the intense global competition fueled by exponential technology growth that is reshaping the corporate landscape. This research theme is also inspired by the desire for resilience in innovation. By empowering thinkers and doers, tools in collaborative environments allow researchers to share and test their mental models rapidly, and amplify their productivity systematically.

Martha G Russell

martha.russell@stanford.edu

Executive Director

mediaX Team

Susana Montes

susanam@stanford.edu

Communications Manager

Adelaide Dawes

adelaide@stanford.edu

Program Manager

Directing States of Mind Through Non-verbal Behavior Using the Microsoft Kinect

Research Team: Jeremy Bailson, Associate Professor of Communication; Andrea Stevenson Won, PhD Candidate, Department of Communication; Wenqing Dai, Graduate Student, Computer Science; Le Yu, Graduate Student, Computer Science.

Overall Project Goals

What if we could automatically detect how well a group is "synching" on a collaborative project? An early concept developed by psychologist Adam Kendon in the 1970's was "interactional synchrony." Nonverbal and verbal behaviors in a group are tied together in what Kendon calls "an intricate dance." When a group is firing on all cylinders, being productive and creative, that nonverbal dance is an amazing, synchronized experience. Using technological approaches derived from Bailenson's lab, the team plans on using inexpensive commercial videogame platforms to assess (and then to predict) collaborative innovation. The research strategy will operate in three phases:

1. Use game technology (e.g., Microsoft Kinect) to track multiple collaborators' nonverbal behavior during a creativity group task.

2. Differentiate groups into "high" and "low" innovators based on their performance across many different sessions.

3. Use "bottom up" learning algorithms to differentiate the high innovators from the low innovators based on their nonverbal behavior as detected by the system.

With this system, face–to-face and online collaborations can be monitored from a "thin slice" of a session, and managers will be able to predict future success in these collaborations.

Progress to Date

1. Technological Innovation

The team has created a system that integrates data from two Microsoft Kinects simultaneously (one pointed at each person in a dyad), prevents interference from the opposing infrared emitters, synchronizes the timestamp of the data, and organizes that data into a format that is conducive to feeding into machine learning.

2. Task Construal

The team has designed specific tasks based on learning, collaboration, and creativity that a) are quantitatively measurable, b) show enough variance across people to allow for prediction, c) are based in previous psychological literature on task performance.

3. **Data Collection**

The team has run almost 200 people through an experiment for which the data collection lasted six months. The team ended up with about 70 dyads worth of data (after getting rid of pilot subjects and technological failure). As far as the team knows, this is one of the largest datasets of nonverbal behavior from the body (i.e., as opposed to just the face) that can be paired with outcome measures that has ever been collected.

4. **Teacher/Learning Prediction**

Using machine-learning algorithms, the team has demonstrated that it is possible to predict (with an accuracy of 86 percent, compared to 50 percent chance) the success of a student simply by looking at the nonverbal behavior of the student and a teacher in a pair. This algorithm will work in real-time. The team wrote a paper on this study, which is currently under review at IEEE Transactions on Affective Computing.

5. **Creativity/Collaboration Success**

Using machine-learning algorithms, the team has demonstrated that it is possible to predict (with an accuracy of just below 80 percent, compared to 50 percent chance) how creative a pair will be simply by looking at the nonverbal behavior of the two collaborators. This algorithm will work in real-time. The team has been invited to submit this study as a paper in a special issue of the Journal of Nonvebral Behavior; the submission is due by March 14th.

6. **Synchrony detection**

The team is working on algorithms that quantify the "autocorrelation" of the nonverbal behavior of the two people in both the learning and the creativity tasks. This is a large mathematical procedure, which seeks out patterns inherent to the two people without using an outcome measure (e.g., learning) to organize the movement data. The team has made substantial progress on this project both by a) coming up with a "brute force" mechanism to find patterns based on the raw data, and b) developing visualization tools (with the assistance of the software team from Konica Minolta) that can look at the nonverbal behavior of two people side by side and search "top down" for patterns.

7. **New technological development**

The team is working on using a device that is better than the Kinect—the Xtion Pro Live—to capture larger groups of interactants. In comunication with Konica Minolta's software team, the Stanford research team has begun to work on plugins to make the Xtion work with the current system.

A Journey from Islands of Knowledge to Mutual Understanding in Global Business Meetings

Research Team: Renate Fruchter, Co-founder Project-based Learning Lab; Kincho Law, Professor Environmental and Civil Engineering; Leonard Medlock, Research Assistant, Project-based Learning Lab.

Progress to Date

September – December 2012

09.05.13 – One day briefing at Konica Minolta in Osaka with Takao Shudo and Ikuko Kanazawa

Use Case I: Konica Minolta eMoC Localization

- Ikuko Kanazawa mediaX Visiting Scholar at PBL Lab to work with Dr. Renate Fruchter.
- Identify potential pilot teams.
- Konica Minolta eMoC related data collection related to space and technology.
- eMoC PBL Lab surveys for data collection: background, knowledge work, space and technology.
- eMoC knowledge transfer.
- Konica Minolta rapid prototyping of use case scenarios for eMoC.
- Provide Ikuko with access to eMoC cloud prototype.
- PBL Lab Survey Konica Minolta data analysis and synthesis of findings.
- Correlating survey data with eMoC mock-up prototypes.
- Ms. I and Ms. Field – eMoC storyboard.

January – June 2013

Use Case II: Konica Minolta eMoC Localization

- Ikuko Kanazawa – back in Japan.
- Continue to collect data, discuss and clarify eMoC functionality and benefits (with use case members and Shudo-san).

o Use eMoC to assist a team in modeling their space, collaboration technology use, and potential engagement. Determine how to improve effectiveness of knowledge worker productivity during distributed team meetings.

o Have regular remote meeting sessions (using Go-to-meeting) with Dr. Renate Fruchter to discuss eMoC clarification questions, details of the eMoC pilot and localization.

o Collect specific space and technology information to localize eMoC for pilot deployment. (Tar get: April/May)

o Analyze use case data.

eMoC R&D Ongoing Activities

September – December 2012

o eMoC mobile & cloud rapid prototyping cycles.

o Re-architect the eMoC to address lessons learned from education and industry pilot experiments.

o New eMoC mobile prototype storyboarding.

January – June 2013

o Design, implement, and test eMoC mobile MS Azure cloud backend system.

o Design, implement, and test eMoC mobile GUI and interaction experience.

o Integrate eMoC mobile GUI and MS Azure cloud backend system.

o eMoC mobile testing with PBL research team.

o eMoC mobile-cloud prototype implementation and testing with PBL research team.

o AEC Global Teamwork course testbed experimental deployment and data collection.

Upcoming Event

AAAI Spring Symposium Series Workshop on Shikakeology: Designing Triggers for Behavior Change

at Stanford University. March 25-27, 2013. Co-chairs: Naohiro Matsumura and Renate Fruchter.

Papers

o A Journey from Island of Knowledge to Mutual Understanding, by Renate Fruchter and Leonard Medlock.

o Shikake Trigger Categories, by Naohiro Matsumura and Renate Fruchter.

Next Steps

June – December 2013

o Testbed data analysis

o eMoC documentation, writing paper(s), seek funding for further R&D

The Utility of Calming Technologies in Improving Productivity

Research Team: Neema Moraveji, Director Calming Technologies Lab; Roy Pea, David Jacks Professor of Education and Learning Sciences.

Anticipated and Unanticipated Progress to Date

This academic year, the team set out to make progress on several research areas. Progress was made on some – and on others, the team made pivots to the research plan. This path is outlined below.

Improved Ambulatory Respiration Sensor

The team spent considerable time working on an integrated chip that would be much smaller than the existing "Breathbelt" sensor. This new sensor would be more wearable. The schematic for this work is shown in Figure 1.

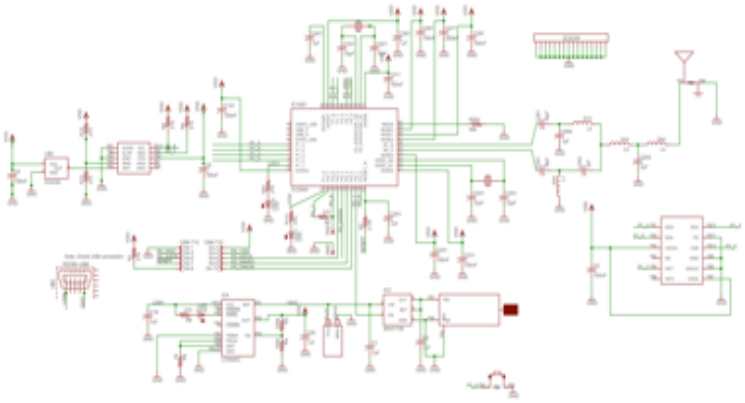


Figure 1: Schematic for integrated chip for miniaturization of the "breathbelt" chip.

Hong Kong-based Brainpage developed a novel breathing sensor that the team decided to use for subsequent research. It is based on a pressure-based sensing mechanism as opposed to the stretch/strain-based method we have been using up until now.

Longitudinal Breathing Pattern Analysis

The team collected ambulatory longitudinal respiration data from five users in the field, over the course of a week. These are some of the first known datasets of this sort. It was shown that, as expected, the respiration rates followed a normal distribution curve (e.g., Figure 2a). However, it was also shown that the breathing pattern of a particular user, who was later found to be a regular meditator, followed a

bimodal distribution pattern (Figure 2b). This characterizes elevated self-regulatory ability towards so-called "sustainable productivity."

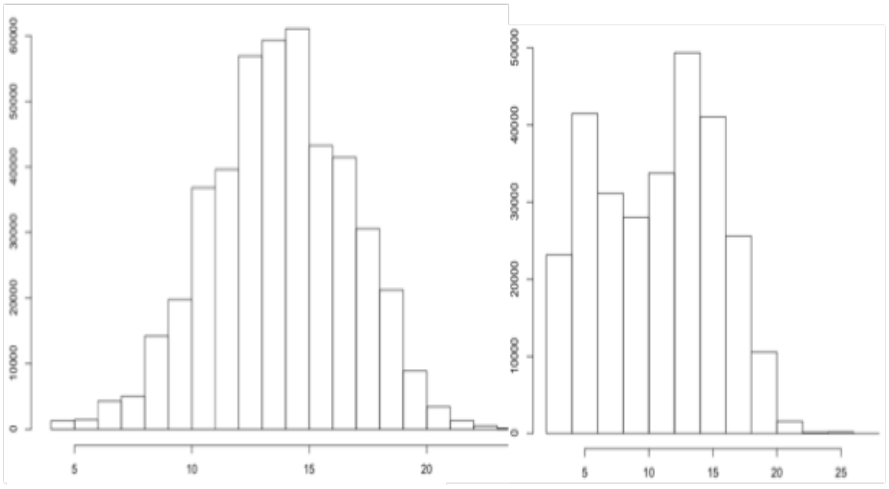


Figure 2a & b: Representative user and the 'self-regulating' user found in longitudinal analysis. The Y-axis is frequency, the X-axis is respiratory rate.

The team was unable to do the month-long study that had been anticipated due to problems getting the sensor to (a) stay on, (b) be comfortable to wear for users, and (c) have long enough battery life.

The self-regulating users from the five-day study demonstrated that they spent significant amounts of time at a slower respiratory rate. The team proposes that calming technologies can help influence users to demonstrate more of a bi-modal distribution or bring mean respiratory rate down.

Multi-sensor Input

The team anticipated they would augment Breathwear with camera-based input, but decided not to. Working with the computer vision techniques was too difficult and it was not feasible to work with the company Cardiio.

Mobile User Interface

Quantitative vs. Qualitative feedback: Users were more interested in qualitative feedback as initial feedback followed by quantitative feedback that helped them precisely understand their performance relative to their own prior performance, as well as social agents.

The team also did some information visualization research into how to support annotation, comprehension, and reflection of one's own respiration data (individual and compared to relevant social groups).

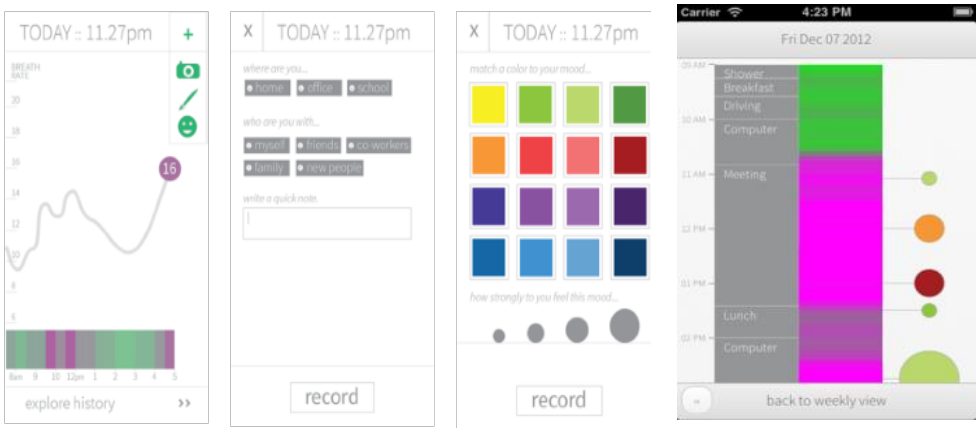


Figure 3: View of instantaneous information that allows users to self-label mood, photos, and other contextual data. The right-most image shows how users can reflect on emotional state that occurred in the past.

The next images show prototypes of other views that help users uncover patterns in their respiratory behavior and comparisons with social groups.

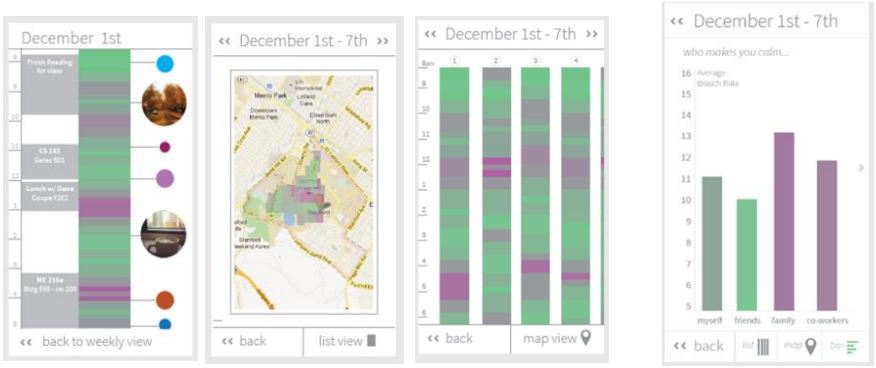


Figure 4: Session Views enable the user to understand their own patterns. The right-most image helps the users compare against their own family and co-workers.

Research Collaborations

The team has been working to support a collaboration with a longitudinal study at UCSF, which will start on April 20.

The team has also entered into research collaboration conversations with Xerox PARC's research lab to support Healthcare and Productivity work.

State-sensitive Information Management

The team anticipated working on at least two research projects around state-sensitive information management – specifically with email (Peacekeeper & DIZ – Daily Inbox Zero) but ended up focusing on user interface techniques before integration with respiration data. These were research projects that had targeted prototypes and users to understand effectiveness. Highlights include:

o **Email Portal:** A task-oriented "start page" that supports users to make tangible their intention before staring at a large inbox and becoming distracted.

o **Lime Time:** A Chrome extension that estimates the time required to work on each email thread and displays that to the user in a color-coded manner.

o **Click Trip:** "Archive" and "Delete" buttons that come alive to train users to effectively manage email overload.

o **ActionMail:** Emotional actions coupled with email operations. Delete gives user an emotional way to 'burn' or 'slice' emails.

o **GmailGarden:** Ambient information visualization that tells users how many email actions they've done and makes users feel accomplished – without disruption.

Work Rythm and Productivity Waves

The team did further work to model what sustainable productivity actually looks like. This work is part of a paper the team is currently writing with Jakob eg Larsen from the Mobile Informatics Lab at the Technical University of Denmark.

One of the first distinctions in the research is between attention and awareness. The difference between the two is that attention is conscious and directed whereas awareness is the lingering, sub-conscious 'residue' of attention. When an information worker moves from the computer to taking a break, they may shift their attention elsewhere but their awareness of their tasks interrupts their ability to sustain attention on a particular foci.

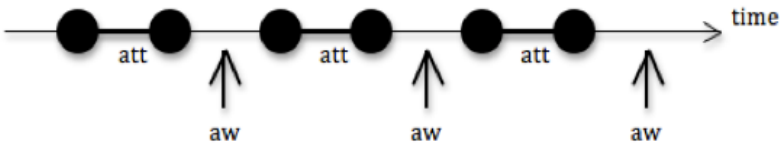


Figure 5: Foci of conscious attention (att) (work-related or otherwise) are often interrupted by sub-conscious awareness (aw), similar to the way interrupts work in an computer operating system.

The importance of this model is to acknowledge that information work has lingering residue that affects knowledge workers' non-work life, affecting their ability to truly rest and recover. Similarly, awareness of non-work tasks interrupts work-related tasks, hindering productivity. The research question becomes, "How can the team design technology to modulate the presence of awareness interruptions?"

The next model (Figure 6) is related to work rhythms to optimize creativity – the team's hypothesis being that mental state influences creativity similarly to (or even more than) external tools. The model shows how the mind shifts between three elusive cognitive states: mind-wandering (undirected, ineffective, anxiety-provoked), task-focused (single-focus, goal-oriented), and pure awareness (non-judgemental awareness of the present moment). This, more than the Yerkes-Dodson curve, the team hypothesizes, captures how real information work is done and why they do not expect, or desire, users to stay only in the task-focused stage.

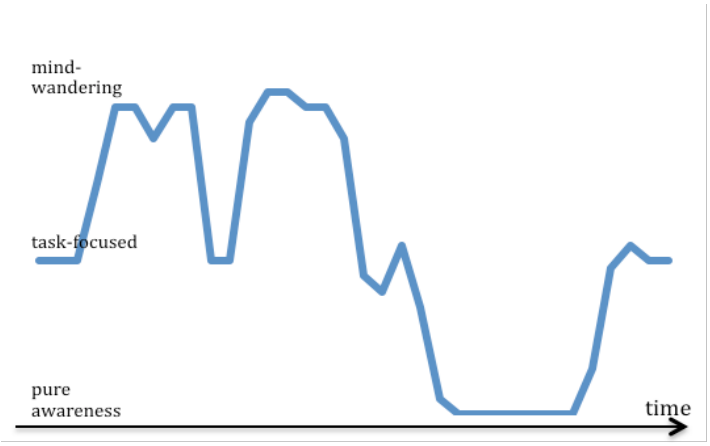


Figure 6: This graph illustrates our hypothesis of how mental state shifts over time and captures cognitive rest and recovery.

Regarding calming technologies writ large, there appears to be an inherent trade-off that seems destructive at first. The team calls this the Presence/Functionality trade-off (See Figure 7).

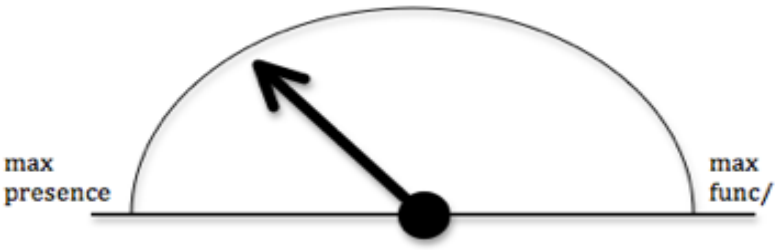


Figure 7: This figure illustrates the trade-off that users must make when they consider how to use a calming technology as it may seem impede short-term productivity to optimize "presence."

Visual vs. Auditory Guidance

The team conducted a comparison between auditory and visual guidance for pacing respiration. The results, shown in Figure 8, show the surprising finding that auditory guidance was more effective at making users slow their breath down, but visual guidance made the users feel subjectively more calm.

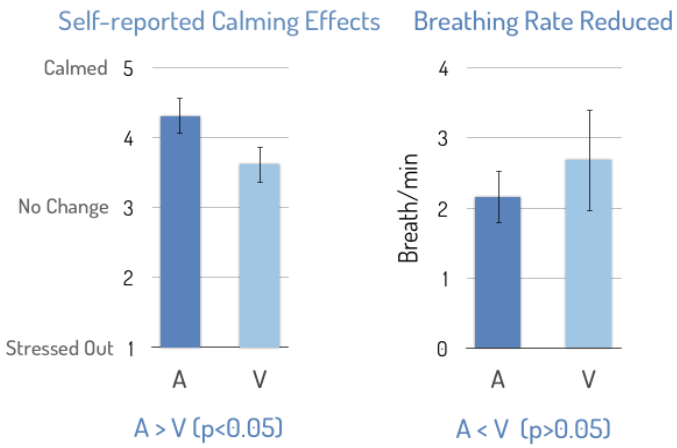


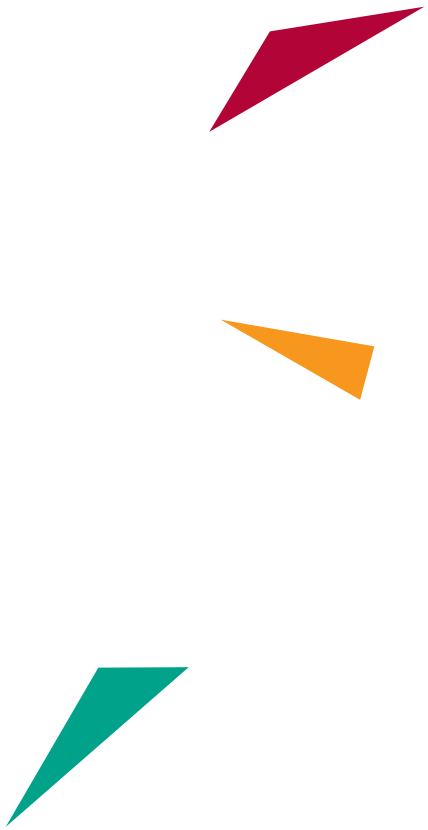
Figure 8: Comparison between auditory (A) and visual (V) breath-pacing techniques on a mobile phone using the breathbelt sensor.

Next Steps

Another area of next steps will be to further explore patterns in self-regulation: When do effective users take breaks and for how long? What are the patterns that effective self-regulators undertake? Answering this will help the team transfer those patterns to users who do not effectively self-regulate – using technological triggers, goal-setting, and so on.

The team will continue to refine their models of sustainable productivity and relate how technologies can be designed to optimize productivity and human wellbeing.

The team's goal is to support "sustainable productivity," and they want to measure cognitive performance as it relates to psychophysiological measures they capture with Breathwear. The team will begin to conduct research into cognitive assessments – either external to the user's information work or within it itself.



The format of this paper is optimized for double-sided printing.