SIGHCI 2023 Proceedings

Special Interest Group on Human-Computer Interaction

1-25-2024

Know Thyself: Improving Interoceptive Ability Through Ambient Biofeedback in the Workplace

Phoebe Chua
National University of Singapore, pchua@nus.edu.sg

Kat Agres
National University of Singapore, katagres@nus.edu.sg

Suranga Nanayakkara
National University of Singapore, suranga@ahlab.org

Recommended Citation

Chua, Phoebe; Agres, Kat; and Nanayakkara, Suranga, "Know Thyself: Improving Interoceptive Ability Through Ambient Biofeedback in the Workplace" (2024). *SIGHCI 2023 Proceedings*. 3.
https://aisel.aisnet.org/sighci2023/3

Know Thyself: Improving interoceptive ability through ambient biofeedback in the workplace

Phoebe Chua
Augmented Human Lab, DISA,
National University of Singapore
pchua@nus.edu.sg

Kat R. Agres
Center for Music and Health,
YSTCM, National
University of Singapore
katagres@nus.edu.sg

Suranga Nanayakkara
Augmented Human Lab, DISA,
National University of Singapore
suranga@ahlab.org

ABSTRACT

Interoception, the perception of the body's internal state, is intimately connected to self-regulation and wellbeing. Grounded in the affective science literature, we design an ambient biofeedback system called Soni-Phy and a lab study to investigate whether, when and how an unobtrusive biofeedback system can be used to improve interoceptive sensibility and accuracy by amplifying a users' internal state. This research has practical significance for the design and improvement of assistive technologies for the workplace.

Keywords

Interoception, biofeedback, assistive augmentation

INTRODUCTION

Wearable sensors, defined as physical sensors that monitor mobility and vital signs such as steps, heart rate and brain activity, provide real-time insights about a user's physical and mental health and performance (Kim et al., 2019). Driven by the growing affordability and capabilities of wearable sensing, the global wearable technology market is expected to be valued at over USD 180 billion by 2030 (Grand View Research, 2022), driven in part by corporate interest in wearable sensing technologies (Kawakami et al., 2023). These technologies have clear applications in the workplace for promoting employee productivity, health and wellbeing (Maltseva, 2020), and indeed have been experimented with to infer cognitive load (Schaule et al., 2018), stress (Mozgovoy, 2019), posture and activity of employees in sedentary jobs (Guitar et al. 2018) and mood (Zenonos et al., 2016).

While promising, existing wearable technologies still suffer from several limitations that may impede their adoption in organizational settings. First, doubts remain about the reliability of inferences made by wearable sensing systems due to issues such as algorithmic bias, lack of sufficient contextual information and disagreement with users' self-perceptions (Kawakami et al., 2023). At the same time, the majority of these systems rely on explicit attention and user motivation for behavior change – for example, if bad posture is detected, a device might beep to alert its user (Jain et al., 2020). While effective, this interaction design is likely to distract the user from their primary task and lead to additional work interruptions, which tend to be detrimental to both work and nonwork outcomes (Chen and Karahanna, 2018). Building on prior work in the fields of affective computing and human-computer interaction (HCI), we aim to address these limitations by shifting away from the lens of predictive wearable systems that claim to recognise what we think and feel. Instead, we draw on the interactional approach (Boehner et al., 2005) as well as a framework for designing interactions for preconscious processes (Jain et al., 2020) to develop Soni-Phy – a biofeedback system that allows users to continuously monitor their internal physiological signals in an unobtrusive manner via ambient audio. Soni-Phy can be thought of as a system that augments users' interoceptive ability (i.e., their ability to perceive internal bodily sensations). We hypothesize that such systems can potentially alter emotion, cognition and behavior with fewer demands on attentional resources, while also circumventing concerns about predictive accuracy.

Our aim is to investigate whether, and how, ambient biofeedback can be used to amplify our perception of internal bodily sensations. We envision that the work will make two primary contributions. First, our findings will shed light on how wearable sensing can be implemented more effectively in the workplace. Additionally, we hope to show that interoceptive ability can be augmented in an unobtrusive manner suitable for knowledge work environments.

BACKGROUND & HYPOTHESES

Interactional systems

The interactional approach was first proposed by Boehner et al. (2005) as an alternative to what they termed the informational approach, where emotion is viewed as a type of information that can be quantified and transmitted from people to computational systems. The informational approach is prevalent in affective computing applications even today, many of which rely heavily on being able to accurately predict or recognise emotions from input data. In contrast, interactional systems view emotion as constructed in interaction. As such, they aim to *co-construct* emotions with users, rather than prescribe an emotion label.

The measure of success for interactional systems is not predictive accuracy – instead, it is the extent to which they can encourage the user to reflect upon their current emotional state. For example, Mirror Ritual (Rajcic and McCormack, 2020) describes a smart mirror equipped with video cameras to detect users' facial expressions. When an individual looks into the mirror, their facial expression is used to generate a unique poem which gently fades onto the mirror's surface. Users are thus encouraged to reflect both on the generated poetry as well as their reaction to it.

Interoception

Interoception refers to the perception and phenomenological experience of the body's internal physiological systems (Ceunen et al., 2016). Interoceptive ability is typically quantified along three dimensions: (i) interoceptive accuracy (measured by performance on objective tests such as counting one's heartbeats); (ii) interoceptive sensibility (self-reported awareness of bodily sensations); and (iii) interoceptive awareness (metacognitive awareness of interoceptive accuracy, measured as the correspondence between interoceptive accuracy and confidence in accuracy) (Garfinkel et al., 2015).

Recent theoretical and empirical advances suggest that there is a strong link between interoception, affect and cognition, making interoceptive ability an attractive potential target for interventions that aim to improve wellbeing. To explain how interoceptive ability influences affective outcomes, we draw on the Theory of Constructed Emotion (TCE; Barrett, 2017). TCE explains that interoceptive signals are categorized by the brain into emotions, resulting in instances of emotion such as fear or happiness. This categorization process has the dual function of allowing us to construct meaningful experiences and act on incoming signals. Indeed, interoceptive sensibility (self-reported awareness of bodily sensations) is positively linked to emotion identification, regulation and use of adaptive coping strategies (Schuette et al., 2019). Interoceptive signals have also been found to guide cognitive outcomes. For example, traders with higher interoceptive accuracy (typically measured by performance on objective tests such as counting one's heartbeats) tended to have higher earnings, suggesting that they are better able to interpret their gut instincts (Critchley and Garfinkel, 2018).

Given the importance of interoceptive accuracy and sensibility in cognitive and affective processes, our first research question was:

RQ1: How can we increase interoceptive accuracy and sensibility?

Interoception is a prime example of a preconscious process, where stimuli naturally operate below the level of conscious awareness but can be made aware given enough attentional resources (Jain et al., 2020). As such, we hypothesize that interoceptive accuracy and sensibility can be improved at little attentional cost by making internal bodily signals more readily perceptible. Biofeedback serves exactly this function, and is also an ideal choice for building interactional systems. By amplifying users' bodily signals, we encourage them to be more mindful of their physiological responses. At the same time, by not assigning labels to users' bodily signals, we encourage them to form their own interpretations of those physiological responses and hence arrive at a clearer understanding of their experiences. Our specific hypotheses are thus:

H1a: The presence of ambient biofeedback will increase interoceptive accuracy.

H1b: The presence of ambient biofeedback will increase interoceptive sensibility.

Biofeedback and Cognitive Resources

Given that we are investigating biofeedback systems in the context of the workplace, a key consideration for the research is the bidirectional relationship between ambient biofeedback (specifically, unobtrusive auditory biofeedback) and users' cognitive resources.

On one hand, auditory biofeedback may influence task performance. The effect of distracting stimuli on cognitive task completion is known to be moderated by the cognitive load of the task as well as by the complexity and acoustic variation of the stimuli (Avila et al., 2012). For example, listening to lyrical music lowers reading comprehension accuracy compared to listening to non-lyrical music or being in a silent environment (Stroupe, 2005), and music tends to be viewed as a distraction when it is played during more complex tasks. However, music enhances performance on simpler tasks such as those that are repetitive or monotonous (Konz, 1962). Because Soni-Phy was designed to be as unobtrusive as possible (Section 3), it is not clear a priori whether and under what task conditions it may influence task performance. As such, our second research question is:

RQ2: Does ambient biofeedback influence task performance?

To gain a comprehensive understanding of how ambient biofeedback might affect task performance in the workplace, we plan to test the following hypotheses:

H2a: The presence of ambient biofeedback will influence task performance.

H2b: The effect of ambient biofeedback on task performance is moderated by the cognitive load induced by the task, such that ambient biofeedback has a more negative effect on task performance as cognitive load of the task increases.

On the other hand, when under high cognitive load, attention to and processing of task-irrelevant sounds tends to decrease (Sorqvist et al., 2012). As such, it is possible that under certain task conditions, users may not be able to benefit from ambient biofeedback. Our final research question is:

RQ3: Does cognitive load moderate the effect of ambient biofeedback on interoceptive accuracy and sensibility?

To understand the boundary conditions on when ambient biofeedback might be used effectively in the workplace, we propose the following hypotheses:

H3a: Cognitive load moderates the effect of ambient biofeedback on interoceptive accuracy, such that the effect of ambient biofeedback on interoceptive accuracy decreases as cognitive load of the task increases.

H3b: Cognitive load moderates the effect of ambient biofeedback on interoceptive sensibility, such that the effect of ambient biofeedback on interoceptive sensibility decreases as cognitive load of the task increases.

Our research model is summarized in Figure 1.

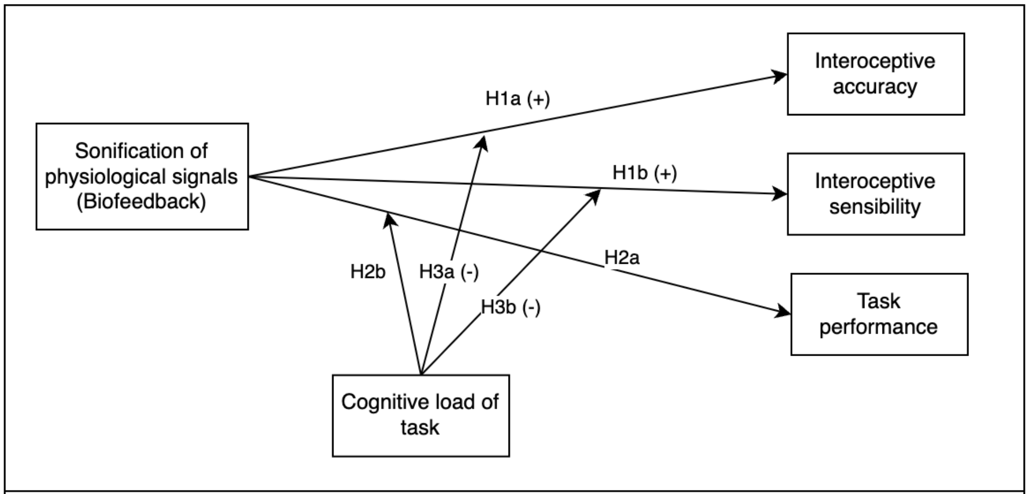

Figure 1: Research Model

MATERIALS AND METHODS

Wearable Sensing System

To test our hypotheses, we developed an interactive wearable sensing system named Soni-Phy. Soni-Phy is a mobile app linked to the Empatica E4 wristband , which can extract physiological signals in real time. This setup enables a user to continuously stream audio that reflects their heartbeat (see Figure 2), providing auditory biofeedback. While several other physiological signals such as skin conductance and electroencephalography (EEG) activity have also been studied in the biofeedback literature, we select the heartbeat signal for sonification – the heart has greater salience for interoception, as evidenced by the prevalence of heartbeat-related tasks in the literature, and is also more accessible to the general population (Winters et al. 2021). We also chose to provide biofeedback through the auditory modality, although the haptic and visual modalities are also common in the biofeedback literature. Given that it is desirable to minimize task disruptions in workplace settings (Chen and Karahanna, 2018), we designed Soni-Phy to deliver biofeedback through a modality not typically required for a users' primary task. This eliminated the visual modality. Between the auditory and haptic modalities, the auditory modality was chosen because of evidence that pleasant audio with low acoustic variation (e.g., nature soundscapes or instrumental music) can support mood with minimal effect on working memory task performance (Avila et al. 2012, Newbold et al. 2017).

In summary, the main function of the Soni-Phy app is to stream audio which pulses gently at a rate that mirrors the user's current heartbeat. To create this effect, we utilize Max, a visual programming language for manipulating audio and other multimedia content in real-time. Our approach involves modulating the volume of a source audio clip by controlling the frequency of a phasor object, which outputs a sawtooth-waveform signal that cyclically ramps from 0 to 1. This frequency is determined by the current inter-beat interval (i.e., the time interval between individual heartbeats), resulting in a sound that pulses in sync with the user's heartbeat. As Soni-Phy is designed to be used over extended periods of time in workplace settings, we source our audio clips from the Affective Responses to Augmented Urban Soundscapes (ARAUS) dataset (Ooi et al. 2023), which contains a rich collection of unobtrusive soundscape recordings. An added advantage of the ARAUS dataset is that each soundscape is labeled with ratings on eight affective dimensions including *pleasant*, *calm* and *eventful*, allowing us to filter out clips that might be too distracting or unpleasant.

To facilitate the experiments, we created two versions of the Soni-Phy app: biofeedback-on and biofeedback-off. In the biofeedback-off version, the audio clips are played as-is. In the biofeedback-on version, the rate of the audio clips' pulse is controlled by the users' heart rate as described above.

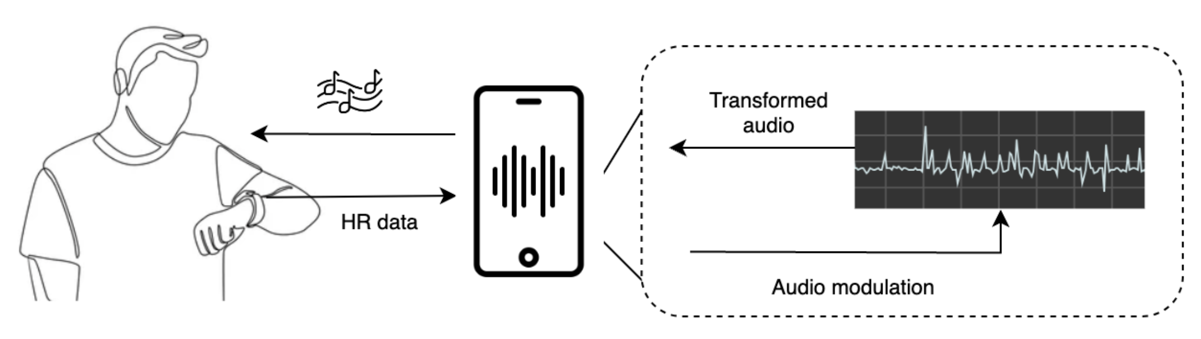

Figure 1: Architecture of the Soni-Phy prototype. A user's heart rate (HR) data is streamed to the Soni-Phy app, which modulates the audio to create a pulse that reflects the user's current heartbeat.

Pilot Testing of the Sensing System

Prior to the lab study, we conducted pilot testing with a sample of 6 participants. The goals of the pilot were to evaluate the usability of Soni-Phy, and to carry out a manipulation check to ensure that Soni-Phy is capable of supporting interoceptive accuracy and sensibility. To assess usability, we employed a concurrent think-aloud method as participants interacted with the app. The think-aloud instructions were worded in line with the standards described by Ericsson and Simon (1993). To verify Soni-Phy's effectiveness at supporting interoceptive accuracy and sensibility, we use the heartbeat tracking task described in Garfinkel et al. (2015).

Participants were first introduced to the Empatica E4 and instructed on its usage. They were then allowed to freely explore the app for five minutes while performing think-aloud. In the pilot version of the app, participants could choose from three different soundscapes from the "bird" class of the ARAUS dataset and could freely switch between the biofeedback-on and biofeedback-off conditions. We specifically chose soundscapes that were rated as maximally pleasant and calm. Then, we administered the heartbeat tracking task in both conditions, using a 30-second trial each time.

Based on feedback from the think-aloud sessions, we compiled a list of modifications to be made to improve the app's usability. Several elements of the user interface caused some confusion during pilot testing; for example, users were unsure of how to interpret the E4 connection status indicator and how to resolve connection issues when they arose. Additionally, the volume level of the soundscapes was not consistent, which occasionally caused discomfort when users switched between soundscapes. Analysis of the manipulation checks showed that interoceptive accuracy, computed as per Equation 1, was higher in the biofeedback-on condition than in the biofeedback-off condition (Mon = 0.901 vs. Moff = 0.609, SDs = 0.062 and 0.224, t(4) = 3.12, p = 0.017). Participants were also more confident in the perceived accuracy of their responses in the biofeedback-on condition compared to the biofeedback-off condition, though this analysis did not reach significance (Mon = 3.50 vs. Moff = 2.50, SDs = 1.22 and 0.837, t(4) = 1.42, p = 0.1115). On the whole, the results of our pilot suggest that Soni-Phy is capable of supporting interoceptive accuracy and sensibility

$$accuracy = 1 - \frac{(|nbeats_{real} - nbeats_{reported}|)}{(nbeats_{real} - nbeats_{reported})/2} \tag{1}$$

On the whole, the results of our pilot suggest that Soni-Phy is capable of supporting interoceptive accuracy and sensibility. As a next step, we plan to carry out a controlled lab study to investigate our stated hypotheses. The lab study is described in detail in the next section.

Lab Study Design

Participants

We plan to recruit a total of 50 participants with normal or corrected-to-normal hearing for lab study, which will be conducted in person. The sample size was calculated according to the computations for statistical power (Chow et al., 2017). Based on a conservative estimate from our pilot studies, we expect to observe moderate to large effect sizes (0.5-0.8) for the hypotheses being tested. A sample size of 50 would allow us to detect large effect sizes and above (effect >= 0.8, statistical power = 0.8, probability level = 0.5).

Experimental Procedures

Before participants enter the lab, we will explain to them (i) the purpose of the study, which is to investigate whether biofeedback can help people be more aware of their bodily sensations, (ii) the evaluation process, and (iii) the working of the wearable sensor (i.e., Empatica E4). After indicating their participation consent, participants will be brought to the research lab. An experimenter will first assist them with wearing the Empatica E4 on their non-dominant hand to ensure that it is properly positioned and data is being streamed. To reduce the risk of motion artifacts on the accuracy of heart rate detection, participants will be asked to try and keep their non-dominant hand still. Then, participants will complete a short survey consisting of questions about their demographic profile and trait interoceptive sensibility. Baseline heart rate will be collected during this time.

The study utilizes a within-subject design, such that every participant performs each experimental task in both the biofeedback-on and biofeedback-off conditions. We utilize three experimental tasks (verbal n-back, Serial Sevens and text summarization) to induce varying levels of cognitive load, with the order of tasks and experimental conditions counterbalanced across different participants to account for order effects. Below, we describe each task in more detail in decreasing order of cognitive load:

- *Verbal n-back.* This is a verbal form of a common delayed-response task (Mehler et al., 2011). The 2-back task induces a high level of cognitive load because it requires participants to hold multiple items in working memory, and also maintain correct sequencing of items. For this task, the experimenter will read out a list of 30 single-digit numbers, and the participant is asked to repeat out loud the number that was read two numbers ago. The list of numbers was randomized and will be kept the same for all participants.
- *Serial Sevens.* In this task, participants will be presented with a randomized three-digit number between 900 and 1000 from which they are instructed to serially subtract in sevens. They are given four minutes and asked to aim for both speed and accuracy. We adapted the task to a web-based environment (Moraveji et al., 2012) to facilitate data collection. Once participants enter their first answer, both their answer and the starting number will disappear from the screen, such that they must remember the previously answered number and subtract from it. This task is expected to induce lesser cognitive load than verbal n-back, as it only requires participants to retain a single item in working memory.
- *Text summarization.* For this task, participants are asked to write a summary of selected WikiHow articles taken from the WikiHow dataset (Koupaee and Wang, 2018) in not more than 150 words. This task is expected to induce the least cognitive load, as participants are performing a relatively simple reading comprehension task, and no time limit is imposed so as not to induce added pressure.

After completing all tasks in the first experimental condition, participants will fill out a brief questionnaire measuring their interoceptive sensibility and accuracy during each task. This procedure is then repeated for the second experimental condition.

Additionally, to increase the generalizability of our potential findings, all participants will be asked to bring to the session some of their own tasks or assignments, which can occupy them for at least 30 minutes. This segment of the study will be split up into two 15-minute chunks, so that like the experimental tasks, every participant will work on their own tasks for 15 minutes in both the biofeedback-on and biofeedback-off conditions. Similarly, the order of experimental conditions will be counterbalanced and participants will fill out a brief questionnaire measuring their interoceptive sensibility and accuracy after each chunk.

Finally, once participants have completed all experimental tasks, we will conduct a short semi-structured interview to better understand their overall experience with Soni-Phy.

Measurement for Independent and Dependent Variables

Interoceptive accuracy

Heartbeat tracking and heartbeat discrimination tasks are the most common methods for measuring interoceptive accuracy. However, in their standard form, these tasks require a participants' full attention (Garfinkel et al., 2015). We adapt the heartbeat tracking methodology to create a simpler measure of interoceptive accuracy that can be used retrospectively. Participants will be asked to report their perceived heart rate for each task on a 7-point scale, with 1 representing "Very low relative to what is normal for me", and 7 representing "Very high relative to what is normal for me". The mean and standard deviation of participants' baseline heart rate will be used to quantify their change in heart rate during the experimental tasks. Finally, interoceptive accuracy will be calculated as the correspondence between participants' answers and the actual change in heart rate.

Interoceptive sensibility

Trait interoceptive sensibility will be measured using the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling et al., 2018). MAIA-2 is a validated and widely used self-report measure of interoceptive bodily awareness, consisting of eight subscales: Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Trust, Self-Regulation and Body Listening. Interoceptive sensibility during the experimental tasks will be measured using participants' confidence judgments in the perceived accuracy of their answers to the heartbeat tracking question described above. Following Garfinkel et al. (2015), confidence ratings will be collected using a slider from 0-100, with a score of 0 indicating a total guess (no heartbeat awareness) while a score of 100 indicates complete confidence (full perception of heartbeat).

Semi-structured interviews

In line with our research questions, our interview protocol will cover two main themes: (i) whether, and how, usage of Soni-Phy supported greater interoceptive sensibility and accuracy, and (ii) whether and how the cognitive load of their primary task impacted the effectiveness of Soni-Phy.

We will also ask participants to briefly describe the task or assignment they brought to the lab and rate its cognitive load.

Data Analysis

Quantitative analysis

To test whether ambient biofeedback had an effect on participants' interoceptive accuracy (H1a) and interoceptive sensibility (H1b), we plan to compare their interoceptive ability scores from the biofeedback-on condition against scores from the biofeedback-off condition. To test whether ambient biofeedback influences task performance (H2), we plan to compare participants' task scores from the biofeedback-on condition against task scores from the biofeedback-off condition. Finally, to test whether cognitive load moderates the effect of ambient biofeedback on interoceptive accuracy (H3a) and interoceptive sensibility (H3b), we plan to compare participants' scores across the experimental tasks that induce varying levels of cognitive load.

Qualitative analysis

We plan to transcribe the interview responses and analyze the transcripts via thematic analysis. Taken together with the findings from the quantitative analyses, we hope to arrive at a holistic understanding of the usage and effects of ambient biofeedback systems in the workplace for improving interoceptive ability.

DISCUSSION AND NEXT STEPS

This paper presents our research in progress to understand whether, and how, ambient biofeedback can be used to amplify our perception of internal bodily sensations. The results of our pilot testing are promising, and suggest that Soni-Phy has a potentially significant positive effect on users' interoceptive accuracy and sensibility in workplace settings. Our next step is to carry out the lab study and data analysis. Subsequently, if our results are significant, we plan to carry out a field study to assess the validity and generalizability of our findings.

Although our proposed study aims to provide novel insights into ambient biofeedback in the workplace, it has some limitations. First, we only investigate wearable sensing in the context of interoceptive accuracy and sensibility. However, evidence suggests that interoceptive ability is linked to positive downstream outcomes such as greater emotional and mental awareness and wellbeing (Barrett et al., 2017; Ceunen et al., 2016; Brewer et al., 2016). Secondly, the environment is highly controlled, and may not reflect real-life working environments faced by typical knowledge workers. If our results are significant, we plan to carry out a longer field study to enable us to assess the generalizability of our findings and the impact of ambient biofeedback on wellbeing outcomes downstream of interoceptive ability. Lastly, the proposed lab study does not explore how design elements of the ambient biofeedback system might moderate H1a and H1b. Further studies could be carried out using a design science research approach to provide recommendations for the design of future systems.

REFERENCES

1. Avila, C., Furnham, A., & McClelland, A. (2012). The influence of distracting familiar vocal music on cognitive performance of introverts and extraverts. Psychology of Music, 40(1), 84-93.
2. Barrett, L. F. (2017). The theory of constructed emotion: an active inference account of interoception and categorization. Social cognitive and affective neuroscience, 12(1), 1-23.
3. Boehner, K., DePaula, R., Dourish, P., & Sengers, P. (2005, August). Affect: from information to interaction. In Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility (pp. 59-68).
4. Brewer, R., Cook, R., & Bird, G. (2016). Alexithymia: a general deficit of interoception. Royal Society open science, 3(10), 150664.
5. Ceunen, E., Vlaeyen, J. W., & Van Diest, I. (2016). On the origin of interoception. Frontiers in psychology, 7, 743.
6. Chen, A., & Karahanna, E. (2018). Life interrupted: The effects of technology-mediated work interruptions on work and nonwork outcomes. MIS quarterly, 42(4), 1023-1042.
7. Chow, S. C., Shao, J., Wang, H., & Lokhnygina, Y. (2017). Sample size calculations in clinical research. CRC press.
8. Critchley, H. D., & Garfinkel, S. N. (2018). The influence of physiological signals on cognition. Current Opinion in Behavioral Sciences, 19, 13-18.
9. Ericsson, K. A., & Simon, H. A. (1993). Protocol analysis: Verbal reports as data, Rev.
10. Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart: distinguishing interoceptive accuracy from interoceptive awareness. Biological psychology, 104, 65-74.
11. Grand View Research. (2022). Wearable Technology Market Share & Trends Report, 2030. https://www.grandviewresearch.com/industry-analysis/wearable-technology-market
12. Guitar, N. A., MacDougall, A., Connelly, D. M., & Knight, E. (2018). Fitbit activity trackers interrupt workplace sedentary behavior: A new application. Workplace health & safety, 66(5), 218-222.
13. Jain, A., Horowitz, A. H., Schoeller, F., Leigh, S. W., Maes, P., & Sra, M. (2020). Designing interactions beyond conscious control: a new model for wearable interfaces. Proceedings of the ACM on interactive, mobile, wearable and ubiquitous technologies, 4(3), 1-23.

14. Kawakami, A., Chowdhary, S., Iqbal, S.T., Liao, Q.V., Olteanu, A., Suh, J.H., & Saha, K. (2023). Sensing Wellbeing in the Workplace, Why and For Whom? Envisioning Impacts with Organizational Stakeholders. ArXiv, abs/2303.06794.
15. Kim, J., Campbell, A. S., de Ávila, B. E. F., & Wang, J. (2019). Wearable biosensors for healthcare monitoring. Nature biotechnology, 37(4), 389-406.
16. Konz, S. A. (1962). The effect of background music on productivity of two different monotonous tasks. Human Factors Society.
17. Koupaee, M., & Wang, W. Y. (2018). Wikihow: A large scale text summarization dataset. arXiv preprint arXiv:1810.09305.
18. Maltseva, K. (2020). Wearables in the workplace: The brave new world of employee engagement. Business Horizons, 63(4), 493-505.
19. Mehler, B., Reimer, B., & Dusek, J. A. (2011). MIT AgeLab delayed digit recall task (n-back). Cambridge, MA: Massachusetts Institute of Technology, 17.
20. Mehling, W. E., Acree, M., Stewart, A., Silas, J., & Jones, A. (2018). The multidimensional assessment of interoceptive awareness, version 2 (MAIA-2). PloS one, 13(12), e0208034.
21. Moraveji, N., Adiseshan, A., & Hagiwara, T. (2012). Breathtray: augmenting respiration self-regulation without cognitive deficit. In CHI'12 Extended Abstracts on Human Factors in Computing Systems (pp. 2405-2410).
22. Mozgovoy, V. (2019, June). Stress pattern recognition through wearable biosensors in the workplace: experimental longitudinal study on the role of motion intensity. In 2019 6th Swiss Conference on Data Science (SDS) (pp. 37-45). IEEE.
23. Newbold, J. W., Luton, J., Cox, A. L., & Gould, S. J. (2017, May). Using nature-based soundscapes to support task performance and mood. In Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems (pp. 2802-2809)
24. Ooi, K., Ong, Z. T., Watcharasupat, K. N., Lam, B., Hong, J. Y., & Gan, W. S. (2023). ARAUS: A large-scale dataset and baseline models of affective responses to augmented urban soundscapes. IEEE Transactions on Affective Computing.
25. Rajcic, N., & McCormack, J. (2020, April). Mirror ritual: An affective interface for emotional self-reflection. In Proceedings of the 2020 CHI conference on human factors in computing systems (pp. 1-13).
26. Schaule, F., Johanssen, J. O., Bruegge, B., & Loftness, V. (2018). Employing consumer wearables to detect office workers' cognitive load for interruption management. Proceedings of the ACM on interactive, mobile, wearable and ubiquitous technologies, 2(1), 1-20.
27. Schuette, S. A., Zucker, N. L., & Smoski, M. J. (2021). Do interoceptive accuracy and interoceptive sensibility predict emotion regulation?. Psychological Research, 85, 1894-1908.
28. Sörqvist, P., Stenfelt, S., & Rönnberg, J. (2012). Working memory capacity and visual–verbal cognitive load modulate auditory–sensory gating in the brainstem: Toward a unified view of attention. Journal of cognitive neuroscience, 24(11), 2147-2154.
29. Stroupe, G. (2005). Comprehension and time difference across no-music, lyrical music, and non-lyrical music groups. Department of Sociology, Emory University, USA.
30. Tsakiris, M., & Critchley, H. (2016). Interoception beyond homeostasis: affect, cognition and mental health. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1708), 20160002.
31. Winters, R. M., Walker, B. N., & Leslie, G. (2021, May). Can you hear my heartbeat?: hearing an expressive biosignal elicits empathy. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (pp. 1-11).
32. Zenonos, A., Khan, A., Kalogridis, G., Vatsikas, S., Lewis, T., & Sooriyabandara, M. (2016, March). HealthyOffice: Mood recognition at work using smartphones and wearable sensors. In 2016 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops) (pp. 1-6). IEEE.