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HUMAN FACTORS

Dossier: Sound in complex environments

De nieuwe factor: Janika Thielecke

The Workplace Vitality Hub

Colofon

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Secretariaat van Human Factors NL
Van Nesstraat 29, 2024 DK Haarlem
leden@humanfactors.nl
www.humanfactors.nl

Redactie
dr. N.W. Wiezer, hoofdredacteur@humanfactors.nl
dr. O.A. Blanson Henkemans, olivier.blansonhenkemans@tno.nl
drs. P. van Dorst, pimvandorst@vhphp.nl
A. van der Have PhD, tuur.vanderhave@kuleuven.be
dr. T. Luger, tessy.luger@med.uni-tuebingen.de
ir. M. Smulders, info@maximsmulders.com
H. Vermeulen, hettyvermeulen@vhp.nl
dr.ir. L.S.G.L. Wauben, l.s.g.l.wauben@hr.nl

Redactieraad
dr. A.H.M. Cremers, prof.dr.ir. J. Dul, drs. J. Jansen, prof.dr. M.P. de Looze, dr.ir. M. Melles, prof.dr.ing. W.B. Verwey

Uitgever in opdracht
Reijseger to the point
Postbus 174, 3760 AD Soest
Telefoon: 035 693 6776
info@reijsegertothepoint.nl

Technische eindredactie
Marit Hazeleger
tvhf@reijsegertothepoint.nl

Realisatie en ontwerp
Practicum, Soest
practicum.nl

Advertenties
Advertentiewinkel.nl
Postbus 174, 3760 AD Soest
Telefoon: 035 693 6776
info@advertentiewinkel.nl

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Inhoud

Met enige regelmaat verblijf ik een paar dagen in een huisje in het buitengebied van een klein dorpje in Friesland. Het 'geluid' dat de eerste avond in Friesland vooral opvalt, is de stilte. Er zijn momenten geweest dat ik daar zelfs wakker van werd. Pas de volgende dag word ik me bewust van de vogels, en het duurt dan nog weer even voordat ik een kieviet, een grutto en een scholekster herken. En dat is ook weer bijzonder, want vogels herken ik alleen maar in Friesland en nooit onderweg naar mijn werk.

Hoe complex geluid en de perceptie van geluid is, en hoe belangrijk dit is in een situatie waarin geluiden letterlijk van levensbelang zijn, zoals in een operatiekamer, wordt duidelijk in het interessante dossier over 'sound in complex environments' dat is samengesteld door Elif Özcan. Een mooi internationaal dossier met artikelen van onderzoekers uit de Verenigde Staten, Engeland en Nederland.

Mentale gezondheid blijft een belangrijke reden voor uitval van werknemers. In sommige sectoren, zoals landbouw, is dit bovendien een onderwerp dat nog niet makkelijk besproken wordt. Janika Thielecke ontwikkelde en evalueerde een eHealth-interventie gericht op het verminderen van werkstress voor boeren in Duitsland. Ze promoveerde op haar onderzoek aan de Technische Universiteit München, en in dit nummer vindt u een samenvatting van haar proefschrift.

Ook in de Workplace Vitality Hub richten ze zich op het versterken van vitaliteit van werknemers. In deze innovatieve werkomgeving wordt een scala aan technologische innovaties uitgeprobeerd en onderzocht. Samenwerking tussen ontwikkelaars, onderzoekers en werkgevers met aandacht voor vitaliteit is de kern van de Workplace Vitality Hub. U treft in dit nummer een beschrijving van een aantal innovaties en een oproep tot samenwerking.

En tot slot: wij zijn als redactie heel erg blij met de toetreding van een nieuw lid: Hetty Vermeulen. Hetty is consultant bij vhp en een collega van Pim van Dorst, die jarenlang redacteur was voor dit tijdschrift. Zij neemt de rol van Pim in de redactie over en zal mee waarborgen dat de artikelen in het tijdschrift toegepast en toegankelijk blijven.

Ik wens u veel leesplezier en alvast een hele mooie zomer.

Noortje Wiezer
Hoofdredacteur
hoofdredacteur@humanfactors.nl

From alarms to infoscapes: sound in the era of complex socio-technological environments

Sound is a phenomenon at the intersection of our daily, functional, social, technological, and environmental experiences. Humans' relationship to sound has been evolving as a result of the complexity imposed upon them by highly-technological systems. Expert users now rely on sound more than ever to be able to convey critical information to other users, monitor and analyze data to detect anomalies or identify patterns in data, and ensure safety and security through alarm systems. Within this complexity, the possibilities offered by system-generated sounds range from an alarm to sonification of (continuous) data. Yet, the design approach to sounds intended for complex socio-technological environments has changed little since the 1950s, disregarding the professional listener's perceptual, cognitive, and emotional needs. In this issue, with three contributions, we aim to disentangle the role and function of sounds in complex socio-technological environments such as intensive care units, operating theatres, and overall intelligent systems used, e.g., by autonomous mobility.

In the first contribution, Cummins et al. discovered a novel way for alarming during surgeries as there are competing needs for sound sources such as music and medical alarms and alarms are often missed due to the masking effect of music preferred by surgical teams. The authors developed a device, CanaryBox, that modulates background music volume based on specified vital sign values. Their approach was crucial in the development of data analysis algorithms that convert raw patient monitor output into controlling the sound environment, connecting data-driven approaches to the ecological role and use of sound.

In the second contribution, Edworthy offers the process of developing new global medical device safety standard for medical alarms (IEC 60601-1-8) and reflects on the need for a new approach which is both evidence-driven and design-driven considering the perceptual capacity of healthcare professionals in action. Consequently, the previously confusing tonal alarms have been replaced by meaningful and heavily tested auditory icon alarms, which are superior along several key performance criteria. Edworthy and her colleagues' work is a great example of breakthrough research in challenging the norm for alarms and their medical representation for immediate and relevant action to increase compliance without annoyance.

In the final contribution, van Egmond criticizes the byproduct of current automated and intelligent systems (e.g., self-driving cars, patient monitoring systems) for offering excessive amounts of information that exceeds humans' perceptual and cognitive ability to process. For example, cacophony created by alarms and other auditory signals and cues eventually cause perceptual fatigue. The author further connects human information processing to how technological systems should acquire and process information in the world and introduces the concept of 'Infoscapes' to improve communication between (intelligent) systems and humans. The premise of infoscapes is based on understanding how humans naturally interpret the physical world and its use in a multi-modal way. According to van Egmond's approach, auditory information is no longer a perceptual-only phenomenon thus its design requires contextual inquiry supported or enhanced by other modalities.

All these contributions in this special issue on sound emphasize the evolving role of sound phenomena in our daily and professional lives encouraging design practices to be sound driven but not sound focused. Sound-driven solu-tions can then manifest themselves on the levels of improving sound quality for better perceptual processing, engineering products and systems that incorporate sound for better operability, and facilitating desired operator behavior towards sounds with better contextual awareness and actionability.

About the author

Elif Özcan
Faculty of Industrial Design Engineering
Delft University of Technology
e.ozcan@tudelft.nl

Modulating music volume in the operating room

Several auditory factors can affect healthcare provider performance, well-being, and patient outcomes. Music volume in the OR is a key factor that can be controlled during time-sensitive situations. Therefore, the research questions for this paper are: does the CanaryBox increase the proportion of alarms that clinicians respond to during surgery, and does it reduce the time clinicians take to respond to alarms? Furthermore, how can we convert data from patient monitoring into usable formats to study how the surgical environment changes affect patient physiology and clinician behavior?

Mabel Cummins, Akash Gururaja, Christy Crockett, Joshua Shive, Joseph Schlesinger

Total noise volume in the operating room (OR) frequently exceeds 100 decibels (dB), significantly surpassing the recommended threshold of 45 A-weighted decibels (dBA) set by the World Health Organization (World Health Organization, 1999; Kracht et al., 2007). Noise in the OR can distract healthcare providers, impair communication between staff, and increase the possibility of errors in patient-related communication (Enser et al., 2017; Keller et al., 2016). Music is frequently played during surgical cases and contributes significantly to the overall noise level in the OR. Music may reduce the stress of the surgical team, but it is also distracting, impairs clinician focus by introducing an exogenous attention draw, and can reduce clinician vigilance to alarms (Narayanan et al., 2022).

The purpose of audible medical alarms is to draw attention to abnormalities in a patient's condition. When responding to an alarm, the clinician must determine the alarm's meaning and intervene appropriately. However, substantial auditory background noise affects their ability to do this, impacting the clinician's response time, accuracy, and ability to understand speech (Bruder et al., 2021; Han et al., 2022). In emergencies, delays in minimizing noise can be critical, so a device that modulates music volume based on alarm status could be advantageous.

In this study, we incorporate the CanaryBox (Canary Sound Design, LLC), an 'intelligent' audio device, into several Vanderbilt University Medical Center (VUMC) operating rooms. This device is 'intelligent' because it receives data from the patient monitor in the operating room and automatically modulates music volume according to the severity of patient vital sign deviations, without clinician input. The CanaryBox (CB) is programmed to lower the music volume by 50% for yellow 'warning' alarms and to shut off the music for red 'crisis' alarms (International Electronical Commission, 2006). Previous studies with the CanaryBox have shown that it is user-friendly, intuitive, and effective in modulating music volume (MacDonald and Schlesinger, 2018; Gururaja et al., 2022). Similar to the Smart and Silent ICU project, which is focused on using smart technologies and algorithms to reduce the frequency of alarms in the ICU, we use the smart technology of the CanaryBox to examine how clinicians' responses to alarms are affected by the noise environment of the OR ('Shhh! SASICU strives for,' 2024).

Methods

To answer the research question, data was collected in 100 total cases in the pediatric orthopedic OR at the Monroe Carell Jr. Children's Hospital at Vanderbilt (Children's Hospital). The CanaryBox device was used in 50 cases, and there were also 50 control cases where the CB was present but not activated. These rooms were chosen based on previous successful implementations of the CanaryBox music modulation protocol (Gururaja et al., 2022). Researchers were scheduled throughout the academic year and summer to attend orthopedic surgical cases at the Children's Hospital and randomly collect intervention or control cases. Any researcher's presence in the OR was approved by the circulating nurse, surgeon, and anesthesia team.

In each case, the CanaryBox was placed on an equipment rack containing the OR speakers next to the nurse's computer station. In both intervention and control cases, the CanaryBox receives audio from the computer and transmits it to the speakers. In intervention cases, the CanaryBox also receives patient vital data of heart rate (HR), blood pressure (BP), and oxygen saturation (SpO_2) from the PIIC iX monitors (Philips) and modulates music volume if vitals fall below certain thresholds. The upper and lower bounds for these thresholds were determined by the anesthesia monitor depending on whether the patient is classified as a pediatric or adult patient and also considers their baseline vitals. Researchers were present throughout each case and monitored the CanaryBox for any malfunctions. After each case, the PIIC iX alarm data containing anesthesia providers' response times to alarms was downloaded.

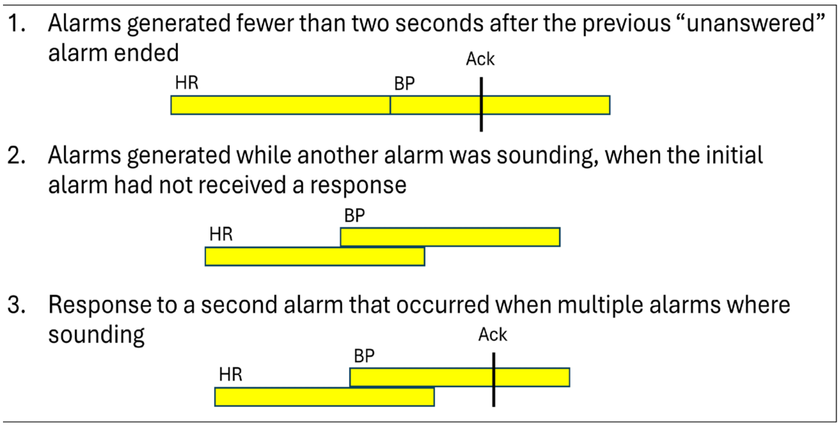

Figure 1. Alarms and responses excluded from further analysis.

Data cleaning

Data was compiled to ensure that only clean cases (cases without interruptions, sufficient music volume, cases containing alarms) were used as part of the 50 intervention and 50 control cases generated at the end of data collection. The obtained PIIC iX dataset contained 5,700 rows of data. Using R (Open Source) and MATLAB (The MathWorks Inc.) scripts, we restructured this dataset into a file containing one line per alarm. We removed 25 alarm notifications from the PIIC iX dataset that met one of two criteria. First, some alarm notifications were doubled. For example, there might be two ‘start’ notifications for the same alarm that occurred within one second of each other. Second, some alarm notifications were ‘orphaned’ (for example, there might be a ‘start’ notification at the end of a case without a corresponding ‘end’ notification, or vice versa). This resulted in a data file containing data about 1035 alarms. The mean case duration was 63.66 minutes (*SD* = 47.30 minutes). On average, 8.66 alarms occurred per case (*SD* = 7.01 alarms). Next, we classified the recorded alarms by type and severity. We classified clinically relevant alarms into three categories: heart rate (HR) alarms, blood pressure (BP) alarms, and blood oxygen saturation alarms (SpO_2). Likewise, we identified the severity of each alarm.

Then, we determined whether each alarm received a response from a clinician. This required several steps. First, we determined whether an alarm occurred alone or along with other alarms. If an alarm occurred alone (i.e., not overlapping with other alarms) and a clinician response (silencing the alarm or pausing all alarms) occurred between the time of the alarm’s onset and its ending, the alarm was coded as having received a response, and the response time was recorded as the time between the alarm’s onset and the time of the response. For this analysis, we only included responses that occurred when only one alarm sounded. Thus, if an alarm was sounding (for example, a yellow heart rate alarm) and a second alarm started (for example, a yellow blood pressure alarm) before the first alarm received a response, we did not include either alarm in further analyses, since it was impossible to tell which alarm the clinician was responding to. This is the situation illustrated at the bottom of Figure 1. Fifteen percent of alarms fell into this category. On the other hand, if the first alarm received a ‘silence’ response and then a second alarm began more than two seconds later, we included both alarms in further analyses.

It is tempting to treat a response to a second alarm that sounds while a previous alarm is still sounding as a response to one event. While it is true that two alarms of the same severity that overlap in time will produce one auditory event, there is a corresponding visual change on the monitor corresponding to the new alarm. This makes it difficult to know whether a clinician response that occurs during the second alarm is a response to the auditory event or to the visual event. For this reason, we chose the conservative approach to dealing with multiple alarms detailed in the previous paragraph. As Figure 1 shows, similar situations occur when two alarms are fewer than two seconds apart, or when two alarms overlap and neither receives a response.

Table 1 shows the counts of clinically relevant alarms. The table shows that blood pressure (BP) alarms were most common at yellow severities. Heart rate (HR) alarms were most common at red severities.

Table 1. Results of clinically relevant alarms.

Severity	Alarm	Condition		Total
		Control	Intervention	
Yellow	BP	206	254	460
	HR	128	168	296
	SpO_2	24	19	43
Red	BP	0	1	1
	HR	22	24	46
	SpO_2	6	3	9
Total		386	469	855

Table 2 shows the proportion of alarms that were acknowledged, grouped by severity. On average, clinicians responded to 70% of alarms that occurred during cases (combining across severities). A chi-square test of these proportions showed that the proportion of alarms receiving clinician responses was higher in the control case than in the intervention case.

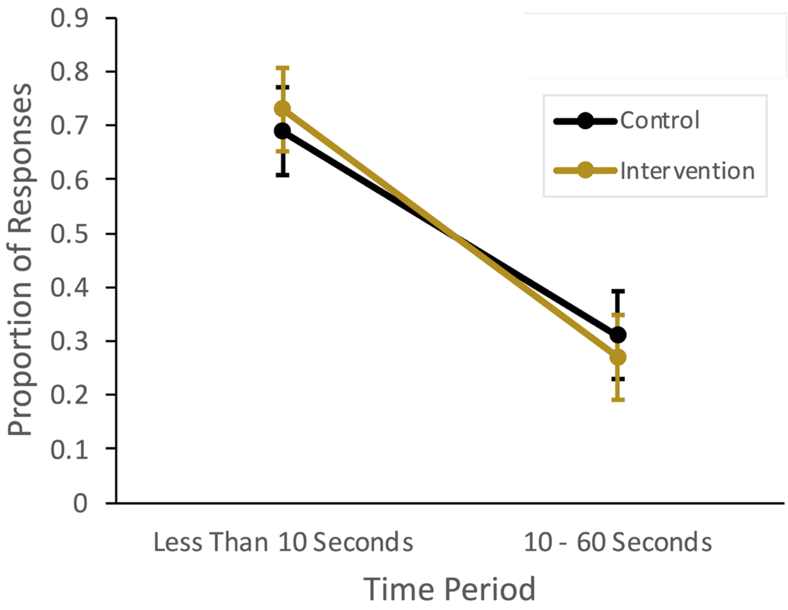

Figure 2. The mean proportion of responses to emergent and urgent alarms in the control and intervention conditions.

Results

Responses to urgent and emergent alarms

We examined whether using the CanaryBox improved clinician responses to emergent and urgent alarms. Emergent alarms are alarms in their first ten seconds of occurrence, and the emergent period was defined as less than or equal to ten seconds after alarm onset. Urgent alarms are alarms that have persisted for more than ten seconds, and the urgent period was defined as from ten seconds to sixty seconds after alarm onset. For each case, we identified responses to emergent and urgent alarms. Then, we calculated the proportion of alarms that occurred during the emergent period and the urgent period. Figure 2 shows the mean proportion of responses to emergent and urgent alarms in the control and intervention conditions. We found a potential 4% increase in responses to emergent alarms when the CanaryBox was used to modulate music volume compared to cases when the CanaryBox was not activated.
Then, we compared these proportions across the control and intervention cases, controlling for case durations and number of alarms. We performed a two-way repeated measures Analysis of Variance using alarm type (emergent vs. urgent) and condition (intervention vs. control) as factors, proportion of responses as the dependent variable, and number of alarms and case duration as covariates. We did not find main effects of alarm type or condition, nor any interaction of these two variables. However, we note that the observed power of the statistical analysis to detect a true effect is only 0.11.

Table 2. Proportion of alarms that were acknowledged, grouped by severity.

Severity	Acknowledged	Condition		Total
		Control	Intervention	
Yellow	No	95	121	216
	Yes	222	264	486
	Proportion Acknowledged	0.70	0.68	0.69
Red	No	0	1	1
	Yes	14	13	27
	Proportion Acknowledged	1.00	0.93	0.96

Discussion

This study examined clinician responses to alarms that occur during surgical cases when an intervention (the CanaryBox) is used to modulate the music volume when alarms occur. We used data collected from a patient monitor about the alarms that occur during a case and the clinicians' interactions with the monitor to evaluate hypotheses about CanaryBox's effectiveness in promoting clinician responses to alarms. We were not able to conclude that the CanaryBox increased clinician responses to emergent alarms. However, the major advance of this project is the development of data analysis algorithms and methods for converting raw patient monitor output files into a format that summarizes the number, type, and severity of alarms generated during a case, as well as clinician responses to those alarms. These tools make it possible to take information that is collected as a normal part of a surgical case and use it to answer questions about whether changes to the surgical environment impact patient physiology and clinician behavior. These data analysis methods could contribute to future studies focused on improving the sound environment in the OR, like the work currently being done by the Smart and Silent ICU project. That project uses 'smart' technology to both reduce the frequency of alarms in

the ICU and detect patients at risk of developing post-intensive care syndrome ('Shhh! SASICU strives for,' 2024). Similarly, the interoperability of the CanaryBox and patient monitoring equipment provides potential opportunities to reduce the cognitive load of clinicians in the operating room and improve patient outcomes.
The lack of evidence in favor of the CanaryBox in our study does not necessarily mean that the CanaryBox does not affect clinician responses during surgical cases. On the contrary, we think it likely that we did not find a positive effect because our study had low statistical power (barely greater than a 10% chance of detecting a true statistically significant effect, according to the results of the ANOVA we used to test for differences in means). Several factors contribute to low-powered studies. While it is possible that the CanaryBox has a real effect that was too small to be detected by our study, we think it is more likely that sources of variability in the naturalistic setting of the study reduced our study's power. Because the data were collected in the operating room (a naturalistic setting), we had no control over the duration of each case, the number, type, or severity of the alarms that occurred during the case, or the strategies that clinicians chose to use to respond to alarms. For example, clinicians could respond to an alarm either by silencing that alarm, which muted only that alarm but did not prevent other alarms from sounding, or by pausing all alarms, which both silenced any current alarms for five minutes, as well as prevented any information about alarm conditions from being written to the PIIC iX data file for the same amount of time.
Our goal is to collect more data with the CanaryBox to improve the power of the statistical analysis. We also plan to conduct lab studies of the CanaryBox to investigate the psychoacoustic features of sound and music in a controlled setting, because the anesthesia team does not wholly have control of the music in the operating room. A lab-based study would allow us to examine responses to music-modulated alarms when confounding factors such as the number of alarms that occur during a case and the duration of a case are controlled across cases. The results of such a study will give us a better sense of the true effect size of music-based interventions such as the CanaryBox, which will, in turn, allow us to plan future naturalistic studies investigating its effectiveness.

Conclusion

The total noise volume in the operating room is loud, and the physical conditions of the operating room contribute to increased physical and mental workload for the clinician. The benefits of music in the operating room are disputable, and its volume may hinder the clinician's response to auditory alarms about the patient. When developing auditory alarms and patient monitoring systems for operating rooms, considerations include reducing the overall noise levels and ensuring that alarms can be discriminated against the background noise. Additionally, because the surgical team typically controls the music being played, clinicians should consider shifting this responsibility to the anesthesia team, which actively monitors the patient's physiological status and can control the music volume and genre as appropriate.
Overall, this study assessed how reducing music volume during alarm events in surgery affects clinician responses to alarms. We implemented the CanaryBox in surgical cases in the OR and collected data about alarm types and clinician responses to the alarms. We developed data analysis algorithms to convert this data to a usable format for analysis of how changes in the surgical environment impact patient physiology and clinician behavior. These results can aid in future studies of alarm volume and in the creation of technologies to improve the performance of surgical staff and the ergonomics of the operating room.

Evaluation of this study on human factors criteria

This study uses a systems approach because it focuses on how the clinician's performance is influenced by the acoustic environment, a factor that significantly impacts the surgical staff's effectiveness yet lacks thorough research. This study is design-driven as it focuses on the elements of the CanaryBox and how to integrate the CanaryBox smoothly with the anesthesia equipment in the operating room. It also considers how sound systems in the operating room can be improved. System performance is also considered because this study considers the performance of clinicians using the CanaryBox device when responding to alarms. Weigl et al. (2016) showed that increased mental workload, process deviations, and disruptions in the operating room resulted in significantly worse technical performance by surgical staff, so all impacts of music must be considered. A future step in this design will be to integrate the CanaryBox, a peripheral device, into current technology like anesthesia machines to improve useability and ergonomics.

Institutional Review Board (Human Subjects)

This study was approved by the Vanderbilt University Institutional Review Board (IRB), IRB #190276.

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Samenvatting

Muziek wordt gebruikt om te ontspannen en efficiënter te werken tijdens operaties, maar de aanwezigheid ervan kan de effectieve controle en aanpak van veranderingen in de vitale functies van patiënten door zorgverleners belemmeren. In dit onderzoek werd nagegaan hoe het

verminderen van het muziekvolume tijdens alarmsituaties in de chirurgie de reacties van clinici op alarmsituaties beïnvloedt. We gebruikten het CanaryBox-apparaat in de operatiekamers van het Vanderbilt University Medical Center. Dit apparaat moduleert het volume van de achtergrondmuziek op basis van bepaalde waarden van de vitale functies. We implementeerden de CanaryBox in 50 chirurgische gevallen en 50 zonder volumemodulatie. We konden niet concluderen dat de CanaryBox de respons van artsen op noodalarmen verhoogde, maar schrijven dit toe aan de lage statistische power van het onderzoek (waargenomen power = 0,11) en niet aan het gebrek aan effectiviteit van de CanaryBox. Het belangrijkste resultaat van deze fase is de ontwikkeling van algoritmen voor gegevensanalyse die de ruwe output van patiëntmonitoren omzetten in bruikbare formaten om te bestuderen hoe veranderingen in de chirurgische omgeving de fysiologie van de patiënt en het gedrag van de arts beïnvloeden.

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Contribution to the human factors criteria
This study examines the volume modulation of music in the OR and its effect on clinicians responding to patient vital sign alarms. This can be used as a foundation for improving the acoustic conditions in the operating room for clinicians.

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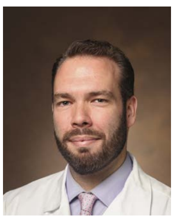
About the authors

Mabel L. Cummins
Department of Anesthesiology, Vanderbilt University Medical Center, Nashville
mabel.cummins@vanderbilt.edu

Akash K. Gururaja
Department of Anesthesiology, Vanderbilt University Medical Center, Nashville

Christy J. Crockett
Department of Anesthesiology, Vanderbilt University Medical Center, Nashville

Joshua Shive
Department of Psychological Sciences and Counseling, Tennessee State University, Nashville



Joseph J. Schlesinger
Division of Critical Care Medicine, Department of Anesthesiology, Vanderbilt University Medical Center, Nashville

SENSORISCH

Meaningful sounds versus meaningless beeps: the case of the international medical device standard

Beeps and tones are ubiquitous in the clinical environment. Their use came about because auditory signals are useful when clinicians are away from the patient and/or attending to other tasks. However, as technology increased, so did the number of alarms, making it possible for alarms to be confused, masked, or otherwise missed. Alarm signals were restricted in quality and variety because the technology used to reproduce the signals was limited in scope. For much, but not all medical technology, this is no longer the case. In this paper, the author describes the process of updating the alarm signals recommended by a global medical device safety standard, IEC 60601-1-8, where the previously confusing tonal alarms have been replaced by meaningful and heavily tested auditory icon alarms, which are superior along several key performance criteria.

Judy Reed Edworthy

In a perfectly designed and fully resourced clinical setting, alarms would never be needed as they should only ever signal when a problem occurs that the clinician is unaware of. However, in reality, alarms are used across all critical safety industries because they inform of danger or potential danger. This is of particular value when the person who needs to know about the problem may be unaware of it developing, or does not have sufficient resources to monitor the problem, or has been called away. System-wide, alarms exist in visual, auditory, and haptic forms and can often work together to provide useful information for the clinician. In this paper, the author focuses on only the auditory aspects of alarms, for a number of reasons. The first is that noise is a problem in clinical areas, and auditory alarms make a substantial contribution to this noise; the second is that the important issue of 'alarm fatigue' makes particular reference to the sounds and noises made by alarms and their disruptive effect on both patients and clinicians; and the third is that specific problems have beset the development and use of clinical auditory alarms due to a combination of historically poor technology, lack of understanding as to how people listen to and process sound, and a slow and somewhat impenetrable standardization process.

In this paper, the author describes the design and testing of clinical auditory alarms that support the most recent version of a global medical device standard. The purpose of the paper is threefold. The first is to show how an evidence-driven approach to the design of alarm sounds can be used to produce improved auditory alarm signals. The second is to describe that process, from design inception to adoption of the new, improved alarm signals. The third purpose is simply to let Human Factors and Ergonomics specialists know that the updated standard exists, is in operation, and (broadly) what it contains within it.

The approach is both evidence-driven and design-driven. Not only does the stand itself contain recommendations for both the design and testing of any new alarms manufacturers may wish to develop, but the standard makes the resultant alarms themselves accessible via download. The development and testing of the new alarm signals are also documented through published, peer-reviewed articles in the public domain. The alarm signals described in this paper are also shown to be considerably easier to learn and localize, are less fatiguing, and impinge less on some aspects of workload than traditional alarms. Thus, they positively influence the well-being of patients and clinicians.

Background

Medical device alarm signals are generally acknowledged to be poor and contribute to the well-known and

publicized problem of 'alarm fatigue', a problem whereby nurses, doctors, and other clinical staff fail to respond to an alarm signal reporting a significant patient problem (Cvach, 2012; Deb & Claudio, 2015; Kristensen et al., 2016).
Many factors contribute to this problem, including a high prevalence of false alarms, too many alarms occurring at once or in a short period of time, alarms that can be masked by one another and by other sounds and noises, and the design of the alarm signals themselves, which are known to be suboptimal.

Medical device alarms are governed by a non-mandatory standard, IEC 60601-1-8 (IEC, 2020). This standard is part of a suite of standards concerned with medical devices and is particularly concerned with medical device safety, and specifies some basic and essential performance and testing requirements for medical devices. The standard also focuses heavily on alarm signals, both visual and auditory, and it specifies a number of risk categories that can be used to signal specific problems, as well as giving specific guidance about alarm urgency. In these respects, the standard is, or should be, very heavily based on Human Factors and Ergonomics (HFE), user-centered principles, as well as principles that can be gleaned from applied cognitive psychology and auditory perception. Until recently however, the standard was based neither on best practice nor what was known about the way people process sound, but was driven by a process that combined a 'best guess' at the solution, the history and progress of standards within this area, and was compounded by the issue that medical alarms could take only a limited range of forms because of the technology used to reproduce the alarms (they could largely only 'beep' or 'ping' because they were generated by simple technology such as piezo devices and so on).

During the period 2016-2020, a project was undertaken to improve the alarm signals associated with the standard. All of the testing and development of the alarm signals are available in the public domain as peer-reviewed articles. The recommended alarms are now downloadable, and significant guidance is provided in the standard should a manufacturer wish to develop their own alarm signals or alarm categories. The standard now represents best practice, is evidence-driven, and will set up the standard for future developments and refinements as the suite of standards is revised.

The story of IEC 60601-1-8

The first edition of IEC 60601-1-8 was published in 2006 and was republished in 2012. A small, interdisciplinary

Contribution to the human factors criteria

According to the human factors and ergonomics criteria (Dul et al., 2012) referred by *Tijdschrift voor Human Factors*, this paper uses a systems approach because it focuses on how the clinician functions in relation to audible alarms within the wider sphere of alarm signaling (which covers visual and haptic alarms also), and how the external acoustic environment (the alarms) influences learning, behaviour, and responses within it. The study is design-driven as it directly addresses how the human predisposition towards listening, responding, and reacting to real rather than artificial sounds can improve audible alarm signals. Alarms are so ubiquitous that improvements in alarms leads to improvements in the whole system, from improving response accuracy and speed on the part of the clinician, to improving the acoustic environment for everyone - patients, clinicians, and visitors. The influence of improving alarms is system-wide.

Table 1. Pitch sequence specifications for alarms supporting IEC 60601-1-8 (2006; 2012). Tones are specified by chroma (C-G) and pitch (where 4 is the fourth octave and C4 is middle C on a piano).

Category	High priority alarm	Medium priority alarm
General	C4-C4-C4-C4-C4	C4-C4-C4
Oxygen	C5-B4-A4-G4-F4	C5-B4-A4
Ventilation	C4-A4-F4-A4-F4	C4-A4-F4
Cardiovascular	C4-E4-G4-G4-C5	C4-E4-G4
Temperature	C4-D4-E4-F4-G4	C4-D4-E4
Drug delivery	C5-D4-G4-C5-D4	C5-D4-G4
Artificial perfusion	C4-F4sharp-C4-C4-F4sharp	C4-F4sharp-C4
Power failure	C5-C4-C4-C5-C4	C5-C4-C4

team developed a set of alarm signals to support the standard (Block et al, 2000). Eight alarms were designated as follows: General (use if not using any specific alarms), Cardiovascular, Ventilation, Oxygenation, Temperature, Drug administration, Artificial perfusion, and Power down. The risk categories are an issue of contention, but these categories remain even in the current version of the standard. The categories come from a risk-and-response approach outlined by Kerr (1985). It is clear that there are other categorization systems that might be appropriate and suitable, but that is another story (Sheffer et al., 2018; Wright et al., 2020).

The alarm signals are specified in detail in the 2006 and 2012 editions of the standard. Each alarm has a high- and medium-priority signal, and each alarm is specified by a tonal sequence, akin to a melody. High-priority alarms consist of five tones (in a repeated 3+2 rhythm), and medium-priority alarms consist of three tones. These rhythms were based on recommendations from an earlier standard concerning anesthesia alarms in respiratory care (IEC 9703:2, 1994), which fell short of recommending specific alarm tones but specified the 3+2 tone (repeated) and the 3 rhythms for high- and medium-priority alarms. These are shown in Table 1. There is also a low-priority signal which is the same for each of the categories.

The standard also made some other stipulations about the alarms to reduce masking, in particular, that they should possess at least four harmonic components between 150Hz and 4kHz, and that none of the harmonics should be more than 15dB different from the others.
Each of the alarm signals, consisting of different melodies, shared the same rhythm as the basic high- and medium-priority rhythms of the earlier specified standard. This unnecessarily increased the homogeneity across the sound set, meaning that while the 3+2 rhythm might have been recognizable as a single alarm, and potentially distinguishable from other unrelated sounds, it was subsequently shown to be difficult to discriminate between the eight individual high-priority alarms (Sanderson et al., 2006; Wee et al., 2008). This comes as no surprise as one of the key publications in the whole of the psychological literature (Miller, 1956, in excess of 42,000 citations) demonstrates that it is easier to discriminate between items, as well as remember them, the more dimensions along which they differ. This paper is about more than simply demonstrating the limits of short-term memory to 7+-2 items, which tends to be the popular opinion of the implications of this paper. Edworthy et al. (2011) demonstrated this in the specific case of alarms, showing that relatively small changes in alarms (making them more different from one another) made the set or alarms as a whole easier to remember. Such was the concern over the tonal alarms associated with the standard that one of the authors of the sounds even published an apologia a few years later (Block, 2008).
The recommendation of 9703:2 (1994) of different rhythms for high- and medium-priority alarms was very much pared down from the original intention, where a set of alarms had been designed in the mid-1980s (Patterson et al., 1986) intended to support the eight risk categories suggested by Kerr (1985). Unlike those supporting 60601-1-8, these alarms varied in number of tones and rhythm, making the alarms potentially more distinguishable from one another. There was also an attempt to mimic the word patterns of the risk categories (for example, the 'Cardiovascular' alarm consisted of 6 evenly-spaced pulses, the first three at a higher pitch than the second; ' the 'Ventilation' alarm consisted of four unevenly spaced pulses and so on). These alarms were generally not welcomed (but without any objective evidence presented as to why they would not work). Atyeo & Sanderson (2015) later demonstrated that those alarms were more learnable and distinguishable than those in the standard, as learning theory would predict, and suggested that these might be adopted in the future. However, technology and science have moved on to the extent that these alarm signals, though better, could be significantly improved upon.
It became increasingly clear that the alarm signals needed updating, particularly as there had been increased impetus to address the 'alarm problem' which was signaled in a very public way through a summit held in Washington DC in October 2011 arranged jointly by the US Food and Drug Agency (FDA), the US Joint Commission in Accreditation of Healthcare Organizations (JCAHO), the Association for the Advancement of Medical Instrumentation (AAMI) and the Emergency Care Research Institute (ECRI) from which the benefits still flow to this day.

The 2020 version of IEC 60601-1-8
Many medical devices, particularly those used in hospital wards, the ICU, and the operating theatre, are equipped with music-quality speakers. They are, therefore, capable of reproducing almost any sound. Some portable devices do not have such sophisticated technology, but even with these types of devices, the use of abstract tonal alarms is not necessarily the best solution. Tones and beeps force the listener into listening to sounds in a way that does not come naturally, for several reasons: until learned, they have no meaning (they are abstract, and people will always find ways to make them less abstract such as adding mnemonics to them); they are often harmonically poor, making them both readily maskable and hard to localize (particularly important in a multi-bed ward where it might be important to identify individual patients quickly), and if more than one alarm sounds simultaneous, they can become confused with one another (Lacherez et al., 2007). This is much less true of real, harmonically rich,

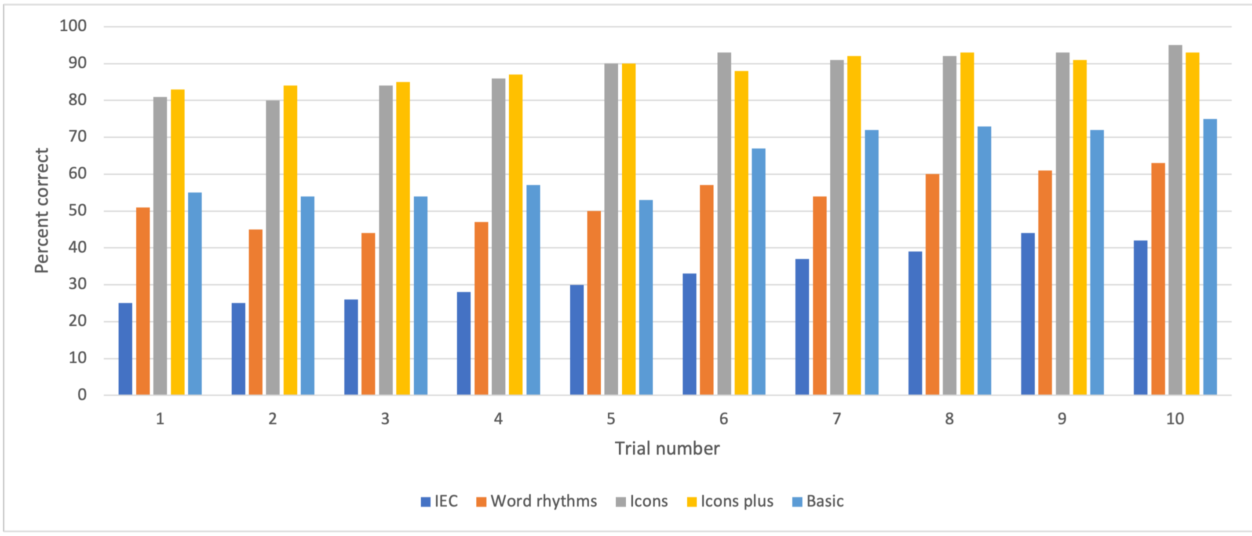


Figure 1. Results of learnability study (Edworthy et al., 2017).

meaningful, everyday sounds. Because technology has improved, we don't need to use unergonomic beeps and tones, we can use real, or reasonably real, sounds. The update to IEC 60601-1-8, which took place between 2017 and 2020, therefore advocates the use of real, if stylized, sounds that can be learned in one or two trials, which are easy to tell apart even when more than one is heard, and which are much easier to localize than harmonically poor artificial and abstract tones. The path showing the design, development, and testing of these new alarms is shown across a series of peer-reviewed papers and are summarized below.

The first paper compared the learnability of five potential sets of alarm signals (Edworthy et al., 2017). Learnability was selected because, aside from being of likely importance in alarm response, it was the only metric known about the 2006/2012 alarms in order to make a meaningful comparison. Five sets of alarms were designed, eight in each set corresponding to the risk categories. The sets tested were the existing tonal alarms, word rhythms where the tonal patterns mimicked the names of the risk categories (à la 9703:2 alarms, shown by Atyeo and Sanderson to be more easily learnable than the official 2006/2012 alarms), a set of 'auditory icons' where the alarm provided an easily-learned metaphor for the category (the most obvious being a heartbeat sound for the cardiovascular category), an enhanced 'auditory icon' set where the sound also had a further embedded sound to signal its urgency and a 'basic' set which were acoustically simpler alarms. Despite their simplicity, these alarm signals tried to provide simple metaphors for the categories (such as a simple rising pitch tone for Temperature). The alarms designed, therefore, covered a range of styles and where the ease or difficulty of learning could largely be predicted. The results are shown in Figure 1. This clearly shows that auditory icons are learned almost immediately, starting at around 80% and further improving after only two or three trials – whereas the existing IEC alarms were still not being recognized with 50% accuracy even after ten trials.

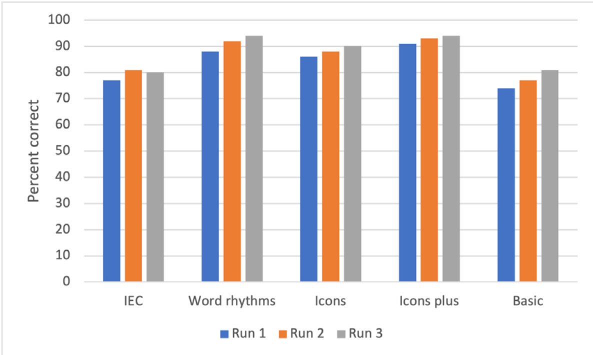


Figure 2. Localizability results (Edworthy et al., 2017).

In the same study, a localizability experiment was carried out, in which participants were required to indicate the direction (of 8 speakers that surrounded them) that each alarm came from. The results are shown in Figure 2. The most acoustically complex alarms (the auditory icons and the word rhythms) were the easiest to localize, while the basic alarms and the existing alarms were harder to localize. The auditory icons and the word rhythms were considerably more harmonically complex than the current set and the 'basic' set.

These findings are not surprising, but it is important to demonstrate them in order to give the alarm's provenance. There is considerable evidence to suggest that auditory icons can act as very effective alarms (Belz et al., 1999; Gaver, 1989; Graham, 1999; Stephan et al., 2006; Stevens et al., 2006). Sounds that are closer in meaning to their referent will be easier to learn (Petocz et al., 2008; Stevens et al., 2009), and sounds that are more different from one another should be easier to learn (Miller, 1956; Edworthy et al., 2011). Localizability is enhanced by greater numbers of har-

monics, especially if they cover a large spectral band so that broadband noise is the most localizable sound (Blauert, 1997; Vaillancourt et al., 2013). A follow-up study demonstrated that the ability of participants to localize an auditory icon when listening to noise and performing a language or number task was equivalent to localizability performance when localizing the current IEC 60601-1-8 alarms without noise or secondary task, at around 75% (Edworthy et al., 2018).
These findings demonstrate that there is an enormous advantage in using auditory icons to signal the risk categories indicated in the standard in terms of two key variables likely to be central to clinicians' ability to identify alarm signals: learnability and localizability, both of which have high face validity.

The preliminary work outlined above was presented to the relevant standard working groups and committees during 2017 and 2018, where it was agreed that the performance of the auditory icon alarms was indeed impressive and that development work should focus on this style of alarms with the aim of incorporating alarms such as these into the new version of the standard. The next phase of the work was to test the candidate alarms in simulation. For this study (McNeer et al., 2018), a group of anesthesiology attendees and residents learned either four new auditory icon alarms or four of the current alarms (which they may have already known). They were then required to carry out two 20-minute simulations, during which each of the alarms sounded several times. They were required to select the meaning of the alarm, and it was recorded whether they were correct or incorrect and how long they took to recognize the alarm. Participants were both significantly faster and more accurate in recognizing the auditory icons. Recognition was around 40% for the current IEC alarms and nearly 90% for the auditory icons, even though participants had never been exposed to alarms of this type before. This study also asked participants to rate their fatigue and workload levels, and it was found that the auditory icon alarms were less demanding on two of the workload and fatigue measures. So again, responses to the auditory icons were faster, more accurate, and less demanding (possibly because they are easier to recognize). A further study (Bennett et al., 2019) demonstrated the relative merits of different auditory icon designs and tested the audibility of the alarms, showing that they are highly audible. The general alarm was audible when presented with noise four times louder. This feeds into the growing body of evidence which suggests that alarms do not need to be the loudest auditory stimulus in the environment, and indeed it is disadvantageous for them to be so (Schlesinger et al., 2018).

Because auditory icons are obvious auditory objects and very distinct from one another, we can also hypothesize that when they are heard together, it will be easier to distinguish between them. This was demonstrated in a recent study where the current (now old) IEC alarms and the auditory icon alarms (now new) were presented to listeners who were asked to identify both the priority and the meaning of simultaneous alarms (Edworthy et al., 2022). Here, the auditory icon alarms outperformed the old IEC alarms, in keeping with other, earlier findings that suggested that simultaneous old IEC alarms merge easily and cannot be differentiated from one another.

The update of the standard

All of the evidence presented in the previous section clearly demonstrates that auditory icons perform significantly better than the old tonal alarms across all measures likely to be of consequence. None of the results are surprising, they can all be predicted from relevant theory, but the point is that the evidence is now in the public domain for anyone to access, the references are listed in the standard, and the resultant alarms are available as a link in the standard to download. The metaphor descriptions of the auditory icons are shown in Table 2. The standard also contains more specific details about the precise acoustic nature of the auditory icon, as demonstrated by the downloadable version of the alarm. All icons are also augmented with a short ‘pointer’ to indicate their priority, except for the general alarm, which only consists of the pointer.

Table 2. Auditory icon metaphors for IEC 60601-1-8 (2020).

Alarm function	Brief description
General	None
Cardiovascular	‘lup-dup’ heartbeat sound
Artificial perfusion	Liquid disturbance water churning, bubbles
Ventilation	Single inhale and exhale
Oxygenation	Irregular, stylized dripping/ saturation
Temperature	Whistling kettle
Drug administration	Shaking pill bottle
Equipment supply/ failure	Starting up a motor that shuts down suddenly

Any manufacturer wishing to use the new alarms can simply download them, place them in their equipment, and trigger them in the way that they would have the old alarms. The standard also has an annex that advises on how they might develop their own alarms, and there is a table of the performance metrics of the alarms for the measures taken during development so that they

can compare performance. There is also advice on what techniques might be used for developing their own alarm and risk categories if they do not wish to use the existing categories.

Compliance with the standard is not compulsory, but manufacturers are keen to claim compliance with IEC 60601-1-8 because it is a safety standard. It also now represents best practices and provides a repository of those best practices. Some manufacturers are now starting to work with these new alarms though there is still a need for a cultural shift whereby thinking about alarm signals, and what an alarm signal needs to do (attract attention and, if possible, give preliminary information about the nature and urgency of the problem), moves on from the use of beeps and tones to more meaningful, and useful, alarm sounds. It was only ever a technological accident that tones and beeps were used at all. It is much more human-centered to use real, or nearly real sounds rather than the artificial and constrained sounds of old technology.

Samenvatting

Piepjes en tonen zijn alomtegenwoordig in de klinische omgeving. Ze worden gebruikt omdat auditieve signalen nuttig zijn als artsen niet bij de patiënt zijn en/of andere taken uitvoeren. Naarmate de technologie echter toenam, nam ook het aantal alarmen toe, waardoor het mogelijk werd dat alarmen verward, gemaskeerd of op een andere manier gemist werden. Alarmsignalen waren beperkt in kwaliteit en variëteit omdat de technologie die gebruikt werd om de signalen te reproduceren beperkt was in reikwijdte. Voor veel, maar niet alle, medische technologie is dit niet langer het geval. In dit artikel beschrijft de auteur het proces van het bijwerken van de alarmsignalen die worden aanbevolen door een wereldwijde veiligheidsnorm voor medische hulpmiddelen, IEC 60601-1-8, waarbij de voorheen verwarrende tonale alarmen zijn vervangen door zinvolle en uitgebreid geteste auditieve pictogramalarmsignalen, die superieur zijn aan diverse belangrijke prestatiecriteria en het gedrag van de arts.

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About the author

Judy Reed Edworthy
Professor emerita of Psychology
University of Plymouth
Devon
J.Edworthy@plymouth.ac.uk

The role of sound in infoscapes: human and technological information processing

In our daily life, we encounter many sources of information or sources that are intended as information. In this essay, the autor focusses on environments containing sources of information that are human-made. He refers to these environments generated by products or systems as infoscapes, analogous to soundscape but as a more general term. Furthermore, in this essay the author makes one other important distinction. He considers information as a concept that is emergent from the processing of the sensed data in the physical outside world (Umgebung), both by human and system and the meaning given to it. This distinction is important because it means that not all data or disturbances in this Umgebung may yield information.

René van Egmond

When I studied in Amsterdam (in a time when there were no mobile phones and fancy noise-canceling headphones), I commuted every day by bus from Haarlem to Amsterdam. During part of that ride, a group of hearing-impaired children traveled to their school. They were a loud bunch, they shouted and had fun. Everybody else on the bus knew when the stop was coming when they got out and 'peace' returned. I tell this story because of the following. For the hearing-impaired children, their perception-action loop was impaired. They were producing sound (action), but they could not or only in a very limited way perceive it (perception). Thus, a cacophony of — for the other passengers — 'meaningless' sounds was filling the bus. For the passengers, the perception-action loop was also impaired, such that no action could be taken to silence the crowd of juveniles. Perhaps everybody (including bus drivers) tried once, but they were not able to communicate with these hearing-impaired children (the children communicated among themselves with sign language and vocal utterances). Consequently, the other passengers could only wait for the desired bus stop where the children got out.

This story functions as an example that can be extended to how people and systems perceive things and act upon them. It also exemplifies Von Uexküll (1909) distinction between *Umwelt* and *Umgebung*, in which the latter is the physical outside world and the Umwelt the inner experience of this outside world. Meaning that every individual organism has its own way of giving meaning to the physical outside world. In the aforementioned example, the passengers versus the hearing-impaired children.

In our daily life, we encounter many sources of information or sources that are intended as information. In this essay, I will focus on environments containing sources of information that are human-made. I will refer to these environments generated by products or systems as infoscapes, analogous to soundscape but as a more general term. I am aware that the term infoscapes is also used in different contexts (Skovira, Borkovich, & Kohun, 2022), but with the rise of intelligent connected systems there is a need in cognitive ergonomics for a term that captures the multitude of informational streams. Furthermore, in this essay I will make one other important distinction. I consider information as a concept that is emergent from the processing of the sensed data in the physical outside world (Umgebung), both by human and system and the meaning given to it. This distinction is important because it means that not all data or disturbances in this Umgebung may yield information.

Analogy between human information processing and technological information processing

In a world where the role of intelligent systems becomes larger, the interpretation of the world by these systems (*Umwelt*) will play an increasingly greater role in human interaction. One of the first issues that plays a role in the interaction between humans and systems is that of trust (De Visser et al., 2020). If intelligent systems are not trusted (undertrust), their actions will not be accepted. If

they are trusted too much, it can lead to overtrust and accidents. Therefore, in the design of intelligent systems, one should be able to strike a perfect balance between over- and undertrust so that a user can be confident enough to use the system. This process in which humans and systems learn to know each other shortcomings and strengths is called trust calibration. Until now, humans have been more capable of adapting than systems. Consequently, trust calibration is a result of an iterative process between humans and systems. By which the human adapts to the shortcomings or to the better analysis of the world by the system. One could also state that if the different interpretations of the world (*Umwelts*) are not similar, this could lead to miscommunication between humans and intelligent systems. Like two people speaking different languages and both do not know the other language. It is, therefore, worthwhile to come up with a conceptual framework that gives a kind of grip on the different *Umwelts* of humans and systems.
The Human Information Processing model has already been presented by Wickens (1992) and has been elaborated on in the work of Proctor and Vu (2010). This model by itself can be seen as a variation of the perception-action loop. Parasuraman, Sheridan and Wickens (2000) already indicated similarities between Human Information Processing and the processing of information by automated systems. In their paper, they exemplified where automation could take over the role of humans. In their proposition, they indicate that, especially in the stage in which critical decisions are made, human decision-making should prevail. In their terminology, the stage in which decision selection on high-risk functions will be made, humans should make these decisions. This was, of course, 24 years ago, but it is still a relevant and ethical aspect that should play a large role in the implementation of technical systems. Especially at this time when AI enables automatic decision-making on much more complex issues. Such as the life-or-death decisions made by the Lavender-system in the current Gaza conflict (Abraham, 2024). This system points to places that should be attacked and bombed. As far as the military state, the system makes fewer mistakes than humans do in the targeting. However, the implementation of this type of

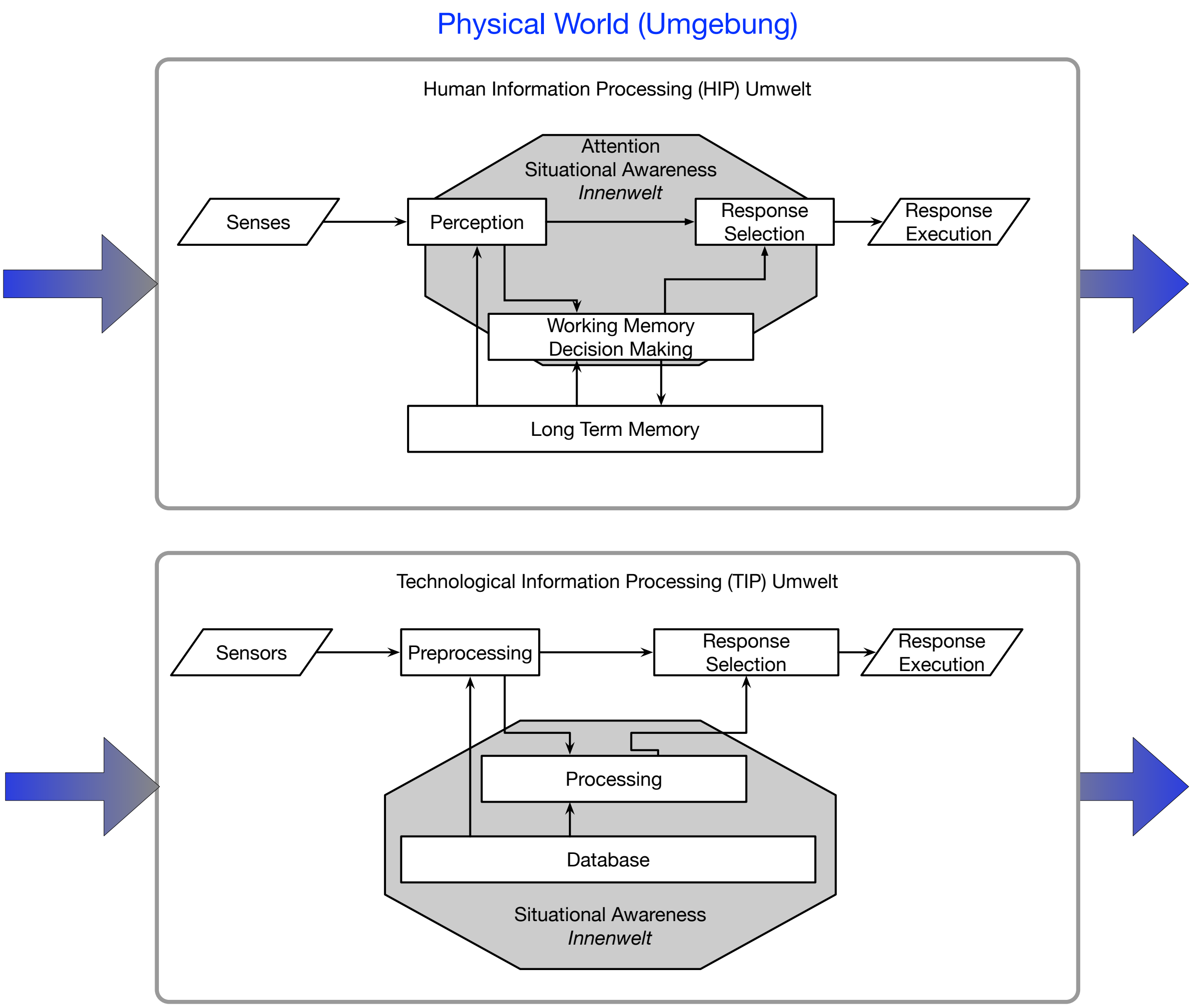

Figure 1. A conceptual framework of Human Information Processing (HIP) and Technical Information Processing (TIP).

system seems to be contradictory, given the implementation of high-risk functions by Parasuraman et al. (2000). Above all, it is an ethical issue if one wants to let a system make death or life decisions. This ethical aspect is not the focus of this paper, and the processing of data that leads to different informational views on the world is the main topic.

Van Egmond, De Ridder, and Bakker (2019) extended this way of thinking, combining the earlier models of Wickens (1992) and Rasmussen (1983). Figure 1 presents a conceptual framework for Information Processing by humans and systems. The physical world (*Umgebung*) is presented in the blue frame around the grey boxes of HIP (Human Information Processing) and TIP (Technological Information Processing). This conceptual framework is a graphical representation of the infoscape. Of course, this is an oversimplification, but I think it gives nice handles for designers and ergonomists to understand why certain interactions take place. The arrows coming out of the HIP and TIP models change color from grey to blue, indicating that the output of the models undergoes perturbations in the outside world, whereas the blue arrow changes from blue to grey to indicate that the data from the physical world undergo interpretations by Information Processing systems. The HIP system consists of three main stages: perceptual encoding, cognitive encoding, and responding (Proctor & Vu, 2010), in which the perception-action loop is extended by a cognitive stage. An elaborate variation of these stages is shown in Figure 1.
The stages in Figure 1 for HIP and TIP are quite similar: (1) sensing the visual world (senses and sensors); (2) creating structure (perception, preprocessing); (3) a cognitive stage (decision making, memory, attention, response selection); (4) action (response execution). The grey blob captures the *Innenwelt*, which could be considered as situational awareness. In this stage, the attribution of meaning and information generation takes place. Although the similarities between HIP and TIP can be readily seen in Figure 1, there are some important differences that need explaining, especially because these differences are the underlying misfit between the *Umwelt* of both systems.
We are familiar with human senses and their capabilities, whereas sensors for the TIP system are different. Although the outside/physical world is the same, the internal representation in HIP and TIP is different. This means that actions taken by both systems will be based on different views of the world. I will focus on three differences: the sensing stage, the perception/preprocessing stage, and the cognitive stage. The human senses consciously used in our daily lives are vision, hearing, tactile-haptic, and smell/taste. A sense like proprioception is subconsciously active. Note that physical events that enter the system via the senses are already preprocessed by the senses (e.g., thresholds, critical bands). In the perception stage of the HIP system, further preprocessing occurs and creates structural information. In my view, the TIP system preprocessing is one specific stage, and the actual structural processing occurs in the TIP's cognitive stage.
In Table 1 I list a number of (human-like) sensors that are used in the automotive industry. Of course, this is not an extensive overview, there are many technical sensors (temperature, position sensors) and sensors that are outside our perceptual range, such as ultrasonic waves (distance), infrared, and radar sensors. Note that these latter sensors are often a combination of omitting and receiving.
I briefly touched upon HIP and TIP's perception and processing stages. I will leave a further elaboration for another time and place. There is one important aspect that needs to be discussed in the cognitive stage of the HIP and TIP system, which is the retrieval and input to the long-term memory or database in the model. As can be seen in Figure 1, the HIP model has two arrows, one for retrieval and the other one for input. Thus, in the HIP model, knowledge generated by information processing will be put into long-term memory in some form. Conversely, the TIP system only supports retrieval. The reason for this is as follows: Currently, AI chip makers like Nvidia put knowledge in their chips generated by external computer systems using deep machine learning algorithms that take considerable time to run. Thus, actionable knowledge on an AI chip of a system can only be internally updated by more powerful external computers that run deep learning algorithms. This is an external process, not an internal process, in the current AI-driven systems. That is the reason that the arrow going from processing to database is missing in the TIP system. In the

Table 1. Human-like Sensors in Automotive.

Modality	Sensor	Event
Auditory	Microphone	Speech, noise detection
Visual	Camera	Interior, fatigue detection Exterior, lane-keeping
Touch/Haptic	Pressure sensor	Steering wheel, Fuel tank - using buoyancy
Smell	Smell sensor	Interior smell
Proprioception	Camera	Lane-keeping

next section, the role of sound will be discussed in relation to the introduction example and the role of sound in an environment like an Intensive Care Unit (ICU).

The role of sound in the infoscape

In the introduction, the HIP systems of bus passengers and hearing-impaired created clearly a different auditory Umwelt of the same physical world. In the ICU, an analogous situation can be observed. A patient monitoring system is equipped with sensors to monitor patients and uses auditory signals to alert the medical staff. However, patient monitoring systems do not have the capability to listen. Thus, they do not experience the sounds that they emit into space (they have no listening sensor). This means that a self-correcting mechanism is not there. The infoscape is, therefore, filled with a multitude of sounds. Furthermore, the medical staff is often busy with other things, and the actual cause of the alarm is not always clear. Thus, for the HIP system of the medical staff, there is often no attribution of meaning to the alarm signal. In this case, the medical staff becomes tired and annoyed by these alarms, which is called alarm fatigue. Therefore, it is not directly obvious which action needs to be taken. Another important aspect that causes alarm fatigue can be derived if one considers the stages of this information processing. In the past, research has focused on the sensory quality of the sounds. The quality can be linked to the perception stage (sensory pleasantness). Although the quality of sounds has improved, medical staff still suffer from stress and alarm fatigue. Bostan, Özcan, Gommers, and Van Egmond (2022) suggested that this aspect is due to task interruption, which is part of the cognitive stage in the HIP system. Consequently, it means that a solution for the reoccurring problems with alarm sounds is not perceptual (sound quality) in nature but cognitive. This means that designers should focus not on improving sound quality but on making the radiating systems more intelligent in order to manage the number of events. In conclusion, an infoscape is filled with many multimodal sources that each are analyzed and interpreted by human and technological systems, resulting in different Umwelts. These are often not similar, resulting in confusion and an unsuccessful calibration process between human and technological systems. In order to understand each other, both technology and humans should understand each other's representation in order to be complementary or supplementary. This will lead to trust and acceptance. The challenge is of course to design systems such that they become as adaptable as humans.

Future steps

What are the implications of the above for future research and design? First, research needs to develop insights how the representations of the world for AI based intelligent systems are similar but also different from the human representation of the world. Note that also humans may use among themselves a different representation of the world which is also often neglected in design. Without this knowledge there will be difficulties with trust in and acceptance of these systems. For example, if a car with automation decides to slow down given a decision made on the interpretation of the sensors and this decision is incongruent with the decision a human would make, this will evoke distrust and an unwillingness to accept this decision. Consequently, humans switch off the automated systems, something that is often observed in automated driving. Second, one of the major challenges will be to develop research paradigms that enable researchers to gain insights in human behavior with AI based intelligent systems. Especially in the design phase of such a system, one would like to know what possible reactions of human users would be. We employed in the Horizon 2020 Mediator project (unpublished) enactment as a possible paradigm, which functioned above expectations. Thus, one participant was the driver, one participant the automated sensing system and a third one made the decisions on the information received by the other two participants. This information could then be infused in the design cycle. Now to return and end with the examples when sound is radiated in the environment without the radiating system sensing what it actually produces. In other words, the feedback loop of the system is not present. One could now imagine intelligent systems that with sensors (e.g., microphone) 'sees/hears/feel' its environment in the same way as humans. In this way, correcting itself by switching of sound/alarms if the noise pollution becomes too high. Does this sound futuristic? If one notices the very fast developments of AI perhaps not.

Samenvatting

Geautomiseerde en intelligente systemen maken een steeds groter deel uit van ons bestaan. Al deze systemen produceren signalen waarvan een mens informatie moet maken. Deze artificiële ruimte van signalen wordt hier aangeduid als *infoscape*. Het probleem is dat niet alle signalen als informatie verwerkt worden. Dit leidt tot een verlies in vertrouwen, acceptatie, et cetera, met als gevolg dat geautomatiseerde systemen worden afgezet. Het is daarom essentieel dat ontwerpers begrijpen wat de verschillende interpretaties van de fysieke wereld zijn en die kennis gebruiken om de communicatie tussen (intelligent) systeem en mens te verbeteren. In de huidige wereld wordt de mens gevraagd om te adapteren aan het systeem, het zou processen verbeteren als de adaptatie tweezijdig zou zijn. Een voorbeeld wordt gegeven en besproken van de situatie in intensive cares waar een kakofonie aan geluiden wordt geproduceerd, die vanuit het 'denken' van het systeem noodzakelijk zijn maar tot frustatie van de medische staf leiden.

Contribution to the human factors criteria

The *Tijdschrift voor Human Factors* lists three criteria taken from Dul et al. (2012) to evaluate this essay. The presented conceptual framework has a *system approach* because it offers an integrated view of the information processes among intelligent systems and humans, which may lead to a more balanced infoscape. It is *design-driven* because the understanding of how systems and humans represent the 'real' world is essential in the design of systems in order to have a complementary division of tasks. It can lead to *better performance and well-being* because the way of thinking affords the incorporating of both worlds and considering their strengths and weaknesses.

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About the author

René van Egmond
Associate Professor
Department of Human Centered Design
Faculty of Industrial Design
Engineering
Delft University of Technology
r.vanegmond@tudelft.nl

GEDRAG

Opportunities and challenges for digital interventions in the prevention of depression

Major Depressive Disorder (commonly just called depression) is a mental health condition characterized by persistent feelings of sadness or a lack of interest in activities, along with other symptoms, such as changes in appetite, sleep patterns, and energy levels over a course of at least two weeks. The disorder is associated with a high burden on the individual with overall increased mortality. At the same time it also causes a high societal burden with reduced productivity and costs associated to sick leave (Bromet et al., 2018).

One in every ten adults experience an episode of depression during their lifetime (Bromet et al., 2018). Although evidence-based treatments for depression exist, structural barriers (e.g., limited service providers and long waiting times) and attitudinal barriers (e.g., perceived stigma and preference to solve one's problems alone) limit their use and effectiveness. Only 1 out of 5 individuals with a depression receives adequate specialist care for their condition (Bromet et al., 2018). In order to reduce the burden associated with depression it is important to find ways to prevent depression, where possible by offering low-threshold support.

Opportunities and challenges for digital interventions in the prevention

My dissertation *Opportunities and challenges for digital interventions in the prevention* reports on the possibilities of the use of digital interventions to offer low-threshold preventive interventions especially to people who already show first symptoms of depression without 'qualifying' for a diagnosis. This stage is called a sub-threshold depression and forms the starting point for indicated prevention.
Indicated prevention has shown to significantly reduce depressive symptom severity and the onset of new full-blown depression cases both in in-person contact (Cuijpers et al., 2021) as well as in online-interventions (Reins et al., 2021). Digital interventions also have additional advantages, such as being mostly independent of time and location, the elimination of travel time and that they can be more anonymous and scalable. At the same time, however, they require more digital literacy and differ widely in the amount of contact with a professional health care provider. Therefore, the first part of my dissertation focused on the opportunities that come with offering further digital interventions for indicated prevention using an example of telephone coaching for farmers in Germany. The second part addresses some of the challenges with regard to providing effective interventions.

Effectiveness of telephone coaching for German farmers

The first part of my dissertation highlighted the opportunities for digital prevention by addressing the question 'How effective is telephone coaching for German farmers compared to treatment as usual in the reduction of depressive symptom severity after 6, 12 and 18 months after study begin?' This question was answered in the project 'With us in balance', aiming at evaluating and implementing different digital solutions for depression preventions for farmers and related professions in Germany. The study included an evaluation of the effectiveness of the telephone coaching in a randomized controlled trial (RCT), whereby participants were randomly assigned to receive up to 850 minutes of personalized telephone coaching or one-time psycho-educational material via e-mail. The primary outcome measure was depressive symptom severity measured with the QIDS-SR16 questionnaire.

The telephone coaching showed to reduce overall depressive symptom severity in the participants, according to an intention-to-treat analysis. It further improved secondary mental health outcomes such as stress, anxiety, and quality of life. The observed effect was comparable to what could be expected based on findings from online and in-person indicated prevention. However, the generalizability of the effectiveness of telephone coaching is limited by the high degree of personalization and the restriction to one occupational group.

An accompanying qualitative interview study with users of the telephone coaching depicted the following. The perceived low effort, the good relationship with the coach and the overall personalization and consideration of the occupational background positively influenced acceptance and satisfaction. It can therefore be concluded that the telephone forms another potential path to deliver preventive interventions. This might especially be the case if occupational circumstances ask for extra personalization.

Explaining effectiveness

The second part of my dissertation addressed the questions 'How can we increase (overall) effectiveness' and 'For whom existing interventions are most effective?' Besides increased evidence for indicated prevention resulting in positive effects averaged across the study populations, it cannot be neglected that not everyone profits (to the same extent) from such an intervention. These challenges were addressed and

PhD candidate:	Janika Thielecke
Promoter:	jun.-prof. dr. Claudia Buntrock
Promoter:	prof. dr. Antonius Schneider
Chairman:	prof. dr. Joachim Hermsdörfer
Promotion:	20 October 2023, Technical University Munich, School of Medicine and Health
Dissertation:	Opportunities and challenges for digital interventions in the prevention of depression


Technische Universität München
TUM School of Medicine and Health

Opportunities and challenges for digital interventions in the prevention of depression

Janika Thielecke

Vollständiger Abdruck der von der TUM School of Medicine and Health der Technischen Universität München zur Erlangung einer

Doktorin der Naturwissenschaften (Dr. rer. nat.)

genehmigten Dissertation.

Vorsitz: Prof. Dr. Joachim Hermsdörfer

Prüfer*innen der Dissertation:

1. Jun.-Prof. Dr. Claudia Buntrock
2. Prof. Dr. Antonius Schneider

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investigated in more standardized web-based interventions, which offer unique opportunities to study these aspects. For these questions, I combined and reanalyzed existing data from RCTs using a method called individual-participant-data (meta-)analysis.

How to make digital interventions more effective?

When looking for methods to increase intervention effectiveness, one starting point is to look at predictors of treatment outcomes. A well-known example in face-to-face therapy is outcome expectancy. However, it is rarely explored in preventive or digital settings. Using data from two RCTs on an indicated prevention online intervention (GET.ON Mood Enhancer) I explored the role of outcome expectancy as a predictor for depressive symptom severity after digital preventive intervention. The effect that outcome expectancy can have on depression outcomes after using a digital prevention intervention was inconclusive but indicated a potential influence in the long run. It becomes apparent that simply transferring elements from face-to-face psychotherapy to digital prevention might be too simplistic and ignores the unique aspects of both prevention and of digital interventions. Since more methodologically sound studies are needed in the new context before building on it to enhance the effectiveness of digital interventions, the corresponding article draws up a research agenda for exploring outcome expectancy in digital prevention. It also raises the question 'what do people expect from (digital) prevention', which has to be answered first.

For whom do digital interventions work?

Besides making intervention more effective as a whole, a step in-between is to identify for whom they already work well. I was especially interested to answer that question in the context of an emerging paradigm called 'indirect prevention' for depression. In indirect prevention, a common, less stigmatized problem like stress, procrastination or – in my study – sleep is addressed, and by improving it this can positively affect depression. In an individual participant data meta-analysis of four web-based sleep intervention trials for employees with insomnia, the indirect approach was shown to reduce depressive symptoms. Most notably, multivariable moderation analysis revealed that from a wide range of sociodemographic, clinical and work-related variables, only depressive symptom severity at baseline showed to moderate the treatment effect. Given that most participants in the trial already had a level of depressive symptom severity that suggests a manifest disorder, it was crucial to see that all effect sizes were comparable to (online) depression treatment as well. The underlying article highlights the need to further look into the mechanisms in interventions to prioritize intervention components for comorbid problems.

Looking ahead

Overall, all studies support the idea of using digital interventions for reducing depressive symptom severity in different populations (i.e. general population, farmers, employees) and were generally in line with prior research. Following a general trend, the importance of finding new ways to personalize preventive offers and target them to the individual situation and needs of participants was noticeable across all studies. In order to enhance the effectiveness of interventions, however, it needs to be clearer when and what needs to be personalized. The interview study on farmers showed that offering them a telephone intervention was a great fit to their needs, given the occupational circumstances. However, this is unlikely to be the first choice of modality for everyone. On the other hand, offering insomnia treatment for individuals with comorbid depression problems seemed beneficial for all employees included in the studies. This indicates a potential to personalize interventions based on clinical characteristics. In conclusion, clarifying what people expect from a preventive intervention could offer much more insight and ways to personalize interventions. While it feels like going back to the start, focusing on what kind of support individuals want, and need, and when they do so, might be the best step forward for (digital) prevention. This asks for more, and serious participatory research, oriented on the user's needs, as well as closer working together between different discipline in the mental health domain.

This text is an adapted version of the summary and discussion of my dissertation. If you are interested in reading the articles included in my dissertation, please get in touch (Janika.Thielecke@tno.nl) or visit my researchgate profile (www.researchgate.net/profile/Janika-Thielecke). The dissertation itself is under embargo until November this year due to unpublished data. After that it will be publicly available.

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ORGANISATIE

Innovatie door technologie in the Workplace Vitality Hub

Oplossingen om de werkomgeving vitaler te maken, hebben de afgelopen jaren een vlucht genomen. Door de COVID-19-pandemie ondervonden we wat het betekent als een gezamenlijke werkomgeving ontbreekt. Ook werd opnieuw duidelijk hoe belangrijk de combinatie van mentale en fysieke gezondheid van mensen voor hun functioneren is. Daarnaast zijn de technologische mogelijkheden om ruimtes en de mensen die daarin werken te kunnen monitoren de laatste jaren enorm uitgebreid. Fontys Hogescholen, Technische Universiteit Eindhoven, imec en TNO werken sinds 2020 samen binnen de Workplace Vitality Hub (WPVH) om de vitaliteit van kantoormedewerkers te bevorderen door middel van technologie en innovatie.

Margreet de Kok, Ida Damen, Bernard Grundlehner, Eveline Kersten en Marieke van Beurden

De Workplace Vitality Hub (WPVH) in Eindhoven is een initiatief van Fontys Hogescholen, Technische Universiteit Eindhoven, imec en TNO met als doel technologietoepassingen te ontwikkelen en realiseren die de vitaliteit op de werkvloer verhogen. Deze toepassingen hebben als belangrijkste themalijnen data en fysieke en mentale gezondheid in de kantooromgeving. Door zowel de omstandigheden in de kantoorruimte als het gedrag van mensen te monitoren, kunnen interventies ontwikkeld worden om beide aspecten aan te passen voor meer vitaliteit. Essentieel daarbij is de informatie die het gebruik van technologie levert waarmee een interventie ontworpen kan worden, maar ook duurzame gedragsverandering ondersteund kan worden doordat bewustwording en feedback met deze informatie mogelijk wordt.
De in dit artikel beschreven voorbeelden zijn een inspiratie en uitnodiging voor geïnteresseerde partijen om contact te zoeken en samen te werken op een maatschappelijke uitdaging die zowel voor preventieve gezondheid als de productiviteit van de werkende beroepsbevolking een positief gevolg zal hebben: vitaliteit op de werkvloer.

Achtergrond

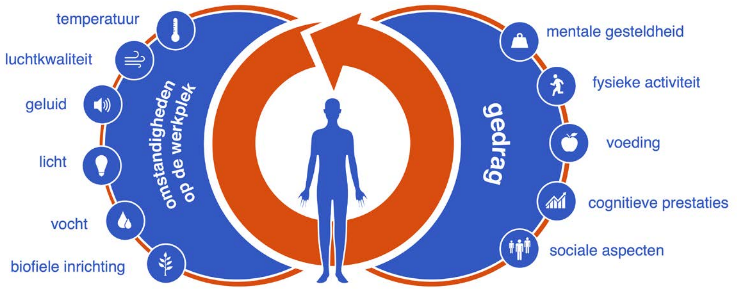
Oplossingen om de werkomgeving vitaler te maken, hebben de afgelopen jaren een vlucht genomen. Door de COVID-19 pandemie ondervonden we, geforceerd en versneld, wat het betekent als een gezamenlijke werkomgeving waarin werknemers elkaar ontmoeten, inspireren en samenwerken, ontbreekt. Ook werd opnieuw duidelijk hoe belangrijk de combinatie van mentale en fysieke gezondheid van mensen voor hun functioneren is (Allen et al., 2016; Leesman, 2022). Het blijft belangrijk om de kantooromgeving te innoveren, gezien de afname van de fysieke conditie door te veel zitten (Formica et al., 2022; Damen et al., 2020) en de toename van mentale problematiek. De afgelopen jaren is het verzuim in organisaties enorm toegenomen. Recent onderzoek laat bijvoorbeeld zien dat een op de zes medewerkers symptomen van burn-out ervaart, zoals slapeloosheid, onrust of emotioneel zijn (Van Veen et al., 2023). Daarnaast hebben veel bedrijven te maken met een krappe arbeidsmarkt, zeker in de Brainport-regio. Vanwege de enorme groei van hoogtechnologische bedrijven is de druk om professionele mensen aan te trekken, in dienst te houden en optimaal te laten presteren groot.
Daarnaast zijn de technologische mogelijkheden om ruimtes en de mensen die daarin werken te kunnen monitoren de laatste jaren ook enorm uitgebreid. Draagbare of geïntegreerde sensoren kunnen (persoonlijke) data verzamelen over langere periodes zonder de persoon te storen, of zelfs ongemerkt. Met behulp van algoritmes en kunstmatige intelligentie kunnen deze data efficiënt omgezet worden in informatie die tot inzicht en ontwerp van interventies leidt. Daarmee is vervolgens ook de werking van de interventie te controleren en de interventie zo nodig aan te passen. Uitdagingen hierbij zijn vormgeving die de privacy waarborgt en maximalisatie van de gebruiksvriendelijkheid.
Sinds 2020 werken Fontys Hogescholen, Technische Universiteit Eindhoven, imec en TNO binnen de Workplace Vitality Hub (WPVH) samen om de vitaliteit van kantoormedewerkers te bevorderen door middel van technologie en innovatie. Standplaats van de WPVH is de High Tech Campus Eindhoven, tevens medegrondlegger van het initiatief. De WPVH is ingericht als living lab voor onderzoek, validatie, implemen-

tatie en voorbereiding van commercialisatie door externe partners, bedrijven die aanhaken op dit onderwerp zoals aanbieders van smart building technologie en inrichtingsconcepten. Vitaliteit wordt in dit verband gedefinieerd zoals TNO en RIVM dat hebben gedaan (Strijk et al., 2015): 'Vitaliteit bestaat uit de dimensies energie, motivatie en veerkracht, waarbij energie wordt gekenmerkt door zich energiek voelen, motivatie door doelen in het leven te stellen en moeite te doen om deze te behalen, en veerkracht door het vermogen om met de dagelijkse problemen en uitdagingen van het leven om te gaan.'

Vitaliteit wordt in de werkomgeving bepaald door fysieke en mentale gezondheid. Betekenisvol werk met voldoende waardering en een goede balans tussen belasting en herstel door in- en ontspanning, zowel mentaal als fysiek, zijn daarbij van belang. De rol die technologie kan spelen in de ontwikkeling, validatie en implementatie van de oplossingen, is het hoofdthema in de innovaties van de WPVH. In de WPVH wordt multidisciplinair naar oplossingen gezocht die een positief effect hebben op vitaliteit: gedragswetenschappelijk, technologisch, sociaal en gezondheidskundig. Dit artikel gaat achtereenvolgens dieper in op de opzet van het living lab en de themalijnen die in de onderzoeksprojecten worden onderscheiden. Daarnaast beschrijft dit artikel een aantal voorbeelden van innovaties en het eindigt met een conclusie.

Opzet van de Workplace Vitality Hub

Op de High Tech Campus in Eindhoven is sinds 2020 een living lab ingericht als dynamische kantooromgeving. Een ruimte van zeshonderd vierkante meter met gesloten meeting rooms, open office, afgeschermde gedeeltes, telefooncabines, presentatie- en demonstratieruimtes. Daarnaast is er technologie voor het bemeten van bezettingsgraad, beweging van mensen, lucht-, geluids- en lichtkwaliteit geïntegreerd. Ook worden additionele sensoren en subjectieve methodes om gedrag en beleving van werknemers te achterhalen, toegepast. Technologie is in de WPVH essentieel om informatie te verzamelen over medewerkers, hun gedrag en de omgeving waarin zij presteren, zodat een (persoonlijke) interventie afgeleid kan worden. De koppeling van kwantitatieve en kwalitatieve data vanuit



Afbeelding 1. Systeembenadering van de Workplace Vitality Hub.

verschillende perspectieven is daarbij belangrijk. De interventie kan bestaan uit het veranderen van omstandigheden, zoals luchtkwaliteit, temperatuur of lichtniveau, maar ook het stimuleren van gedragsverandering door nudging of directere instructie.

De vraagstukken van zowel werkgevers die een zorgplicht hebben ten opzichte van hun werknemers, als aanbieders van oplossingen pakken de multidisciplinaire teams binnen de WPVH op. Deze teams werken de vraagstukken uit, bereiden interventies voor, testen en valideren de oplossingen. De hub ondersteunt commerciële samenwerking tussen partners en publieke organisaties. Daarnaast zijn samenwerkingsverbanden op relevante onderwerpen welkom om aan te haken. De WPVH staat niet alleen open voor nieuwe partners, maar ook voor geïnteresseerde bezoekers of onderzoekers en studenten die zich in een van de onderwerpen willen verdiepen of met hun kennis kunnen bijdragen.

Themalijnen in de multidisciplinaire aanpak van de Workplace Vitality Hub

Data in de kantooromgeving

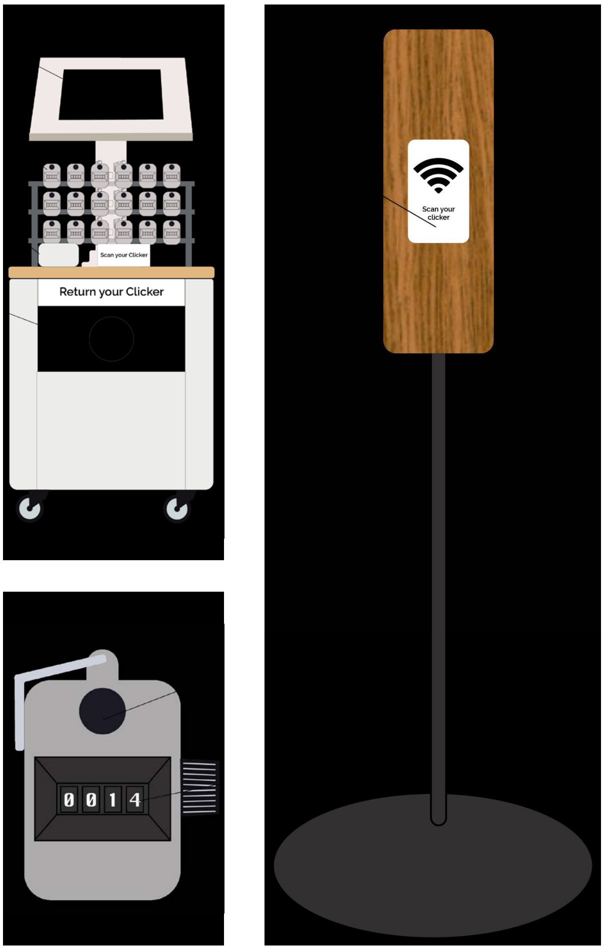
De themalijn 'data' is de centrale spil in het living lab om effecten te kunnen meten van de ontworpen interventies. Data worden verzameld met behulp van een netwerk aan sensoren, waarbij onderscheid wordt gemaakt tussen de volgende categorieën:

1. data afkomstig van sensoren die geïntegreerd zijn in het gebouw, die bijvoorbeeld luchtkwaliteit, bezetting en geluidsniveau meten, maar ook real-time informatie van de koffiemachine en waterdispenser;
2. data die interactie tussen mens en gebouw meten, alsmede de interactie tussen gebruikers onderling, zoals indoor lokalisatie, en sensoren die, bijvoorbeeld op basis van video of radar, scenes kunnen detecteren (denk hierbij aan brainstorming versus geconcentreerd werken versus vergaderen);
3. data afkomstig van individuen, zoals draagbare sensoren (wearables) die fysiologische parameters meten (hartslag, ademhaling, beweging, hersengolven, huidgeleiding) alsmede afgeleide informatie (slaapkwaliteit, stappen, stress), en sensoren die 'op afstand' het individu kunnen monitoren (zithouding, pupilgrootte, et cetera);
4. data afkomstig van vragenlijsten die meer inzicht geven in de persoonlijke achtergrond van de individuen.

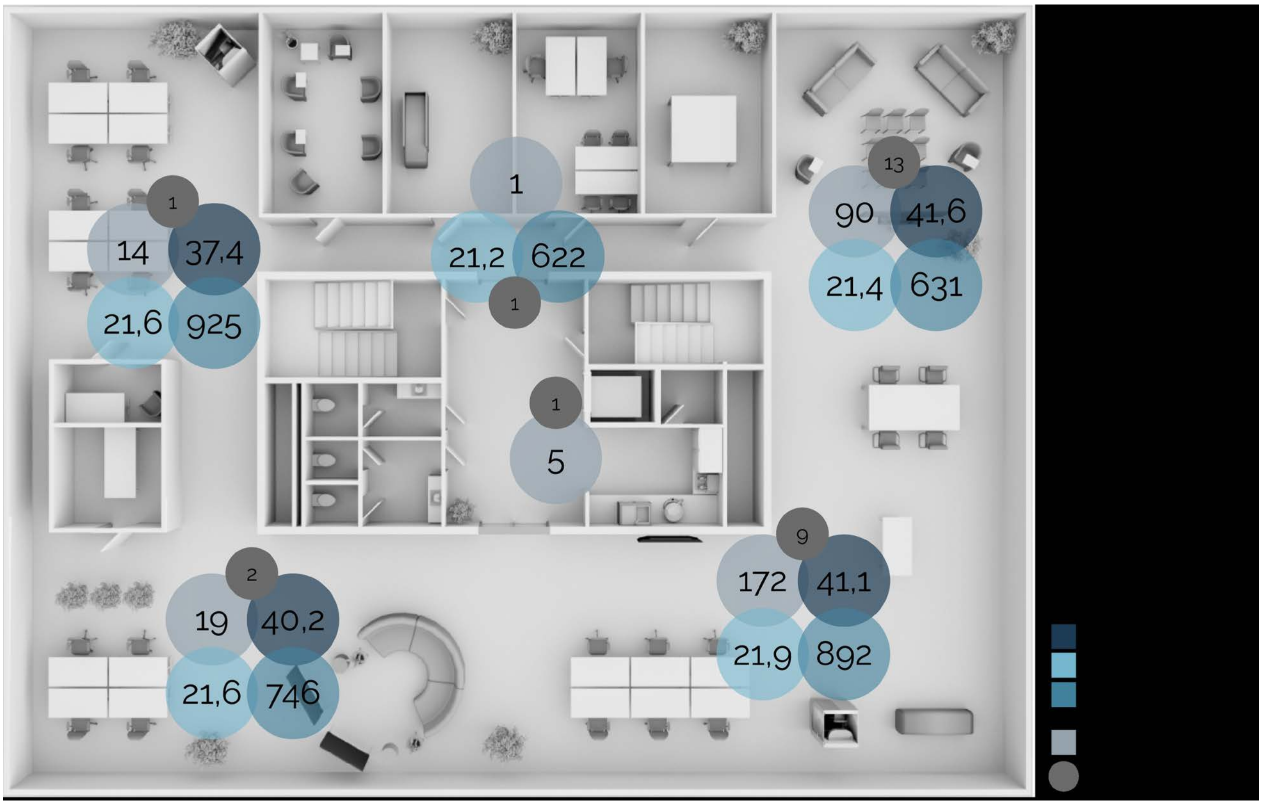
De ambitie is om het sensornetwerk stapsgewijs uit te breiden en te komen tot een dataset waarmee patronen van individuen in kaart gebracht kunnen worden, en de impact van interventies hierop kunnen worden gekwantificeerd. De rol die moderne analysetechnieken (zoals process mining en AI) hierbij kunnen hebben wordt tevens binnen de WPVH uitgebreid onderzocht. Het collecteren van een dergelijke dataset hangt zeer nauw samen met het strikt kunnen controleren wie toegang heeft tot deze data, om de vergaarde persoonsgegevens maximaal te beschermen tegen oneigenlijk gebruik. Een voorbeeld is de recente studie Click-IO (Brombacher, 2024). Hierin is een experience sampling methode gebruikt op basis van eenvoudige analoge tellertjes ('clickers') die door middel van een klik het aantal 'ervaringen' optellen.

De medewerkers in de WPVH werd aan het begin van de dag gevraagd een tellertje mee te nemen. De challenge is een telbare vraag (bijvoorbeeld beginnend met 'hoe vaak') omtrent welbevinden of gedrag, zoals 'hoe vaak verloor je je concentratie? Wanneer ze een werkplek hadden uitgezocht, moesten deelnemers de dichtstbijzijnde 'clicker scanner' aanraken met de clicker. Afhankelijk van de challenge kon de medewerker klikken wanneer aan de voorwaarde van de challenge was voldaan. Challenges hadden uiteenlopende onderwerpen, zoals comfort, gemoedstoestand en sociale interacties. Door het gebruik van de 'clicker scanner' werd de dimensie 'locatie' toegevoegd, waardoor de gegevens te combineren waren met omgevingsensoriek.

Hieronder volgt een resultaat rondom concentratie. Afgaande op het aantal clicks, wordt duidelijk dat medewerkers vooral hun concentratie verliezen in de ruimtes rechtsonder en rechtsboven, maar dat deze ruimtes niet noodzakelijkerwijs rumoeriger zijn ('Decibel'), of verstoken zijn van frisse lucht ('CO_2'). Deze ruimtes zijn dan ook ingericht om interactie te



Afbeelding 2a. Componenten gebruikt in de Click-IO-studie.



Afbeelding 2b. Voorbeeld van een uitkomst van de Click-IO-studie.

bevorderen. Het voorbeeld maakt duidelijk dat de subjectieve ervaring zich in dit geval niet makkelijk laat vatten in sensorische data alleen, maar wel duidelijk kwantificeerbaar is met de gebruikte methode in deze studie.

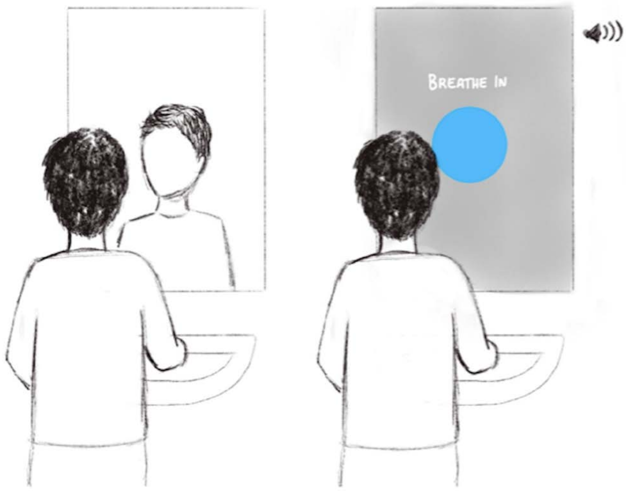
Fysieke kantooromgeving

De fysieke inrichting van kantoren kan in belangrijke mate de vitaliteit van werknemers ondersteunen. Dit vereist een ontwerp dat niet alleen functioneel is, maar ook de gezondheid en het welzijn van werknemers actief ondersteunt. Binnen de themalijn 'fysieke kantooromgeving' worden drie leidende thema's onderzocht: Experience Design, Physicalizing en Work-in-Motion. Deze thema's vormen de basis voor innovaties die zich richten op het verbeteren van zowel de mentale als fysieke gezondheid van werknemers, het stimuleren van innovatie en het positief beïnvloeden van de bedrijfscultuur.

Experience Design richt zich op het creëren van optimale gebruikerservaringen. Het doel is om werkplekken te creëren die niet alleen functioneel zijn, maar ook inspirerend en stimulerend werken. Hierbij wordt gekeken naar hoe visuele, auditieve en tactiele en biofiele stimuli een positieve bijdrage kunnen leveren aan de vitaliteit van de kantoormedewerker.

Physicalizing gaat over het tastbaar maken van (abstracte) vitaliteitsconcepten zoals welzijn, stress en ontspanning. Dit doen we door middel van concrete interventies en prototypes die vitaliteit op de werkplek ondersteunen. Denk hierbij aan het zichtbaar maken van langdurig zitgedrag (zie afbeelding 3) of het zichtbaar maken van de effecten van ademhaling op de vitaliteit (zie afbeelding 4).

Afbeelding 3. Ivy, een kwalitatieve interface om zitgedrag in de kantooromgeving weer te geven (Damen et al., 2020c).



Afbeelding 4. Concept drawing of the Reflex-In mirror, graduation project of Rocio Molina Barea (2023).

Work-in-Motion focust op het optimaliseren van 'werken in beweging' door innovatieve oplossingen. De focus op mobiele en flexibele werkvormen, zoals wandelvergaderingen, stimuleert een cultuur waarin beweging een integraal onderdeel van de werkdag is. Multidisiciplinaire teams ontwikkelen en testen innovaties die het eenvoudiger maken om staand of in beweging te werken.

Een sprekend voorbeeld van een ‘work-in-motion’ onderzoeksproject is de workwalk (zie afbeelding 5). Dit project promoot wandelvergaderingen als alternatief voor traditionele zitvergaderingen door middel van een duidelijk aangegeven route, ontmoetingspunten en de mogelijkheid om een workwalk te boeken. Door de workwalk als onderzoeksinstument in een living lab-omgeving te onderzoeken, kon bestudeerd worden wat de drijfveren en barrières van wandelend vergaderen zijn. Drijfveren voor wandelend vergaderen waren onder meer een andere sociale dynamiek tijdens het overleg, een beter besef van tijd en het stress verlagende karakter (Damen et al., 2020b). Als barrières werden bijvoorbeeld genoemd: het weer, de sociale barrière om iemand te vragen voor een wandeloverleg en het maken van notities of geven van presentaties.

Deze laatste barrière bood aanleiding voor de ontwikkeling van 'hubs’ (zie afbeelding 6). Deze sta-vergaderstations ondersteunen diverse werkgerelateerde taken en vormen een netwerk van herkenningspunten. De hubs, uitgerust met geïntegreerde laptops en RFID-(radio-frequentie identificatie) scanners, faciliteren een naadloze integratie van werkprocessen in een mobiele setting.

De combinatie van deze thema's en projecten schetst een toekomstbeeld waarin de fysieke kantooromgeving niet alleen de vitaliteit en het welzijn van werknemers verhoogt, maar ook een bron van innovatie en

Afbeelding 5. Workwalk met hubs op de High Tech-campus te Eindhoven.

Afbeelding 6. Inchecken bij een 'hub' door middel van een RFID tag (Damen et al., 2021).

positieve bedrijfscultuur wordt. Door de kantooromgeving aan te passen aan de behoeften en activiteiten van de moderne werknemer, wordt de basis voor een gezondere, meer dynamische en inspirerende werkplek gelegd.

Mentale gezondheid

De themalijn mentale gezondheid heeft tot doel bij te dragen aan het voorkomen van stress of burn-out in de werkomgeving. Het meten en stimuleren van veerkracht en floreren (flourishing) om daarmee medewerkers bijzonder te laten presteren, is de aanpak. Onderzoeksvragen zijn: op welke manier worden medewerkers veerkrachtiger, en hoe floreren ze meer? Er wordt over langere termijn gemonitord en er worden met behulp van interventies, testen en meten methodes ontwikkeld om individuen, teams en organisaties verder op weg te helpen. Er worden experimenten gedaan met licht, tools voor ontspanning – zoals een massagebed – en wearables voor zelfinzicht. Door bezinning op thema's als psychologische veiligheid, taboes te doorbreken en het gesprek over mentale fitheid actief aan te gaan in de werkomgeving wordt geleerd hoe dit positief in te zetten.

In Aziatische of Zuid-Europese culturen is het doen van een powernap om te ontspannen en energie op te doen geaccepteerd en wordt daarom gepraktiseerd. In Noordwest-Europese culturen wordt 'slapen in de tijd van de baas' minder gewaardeerd. Wanneer privacy niet gewaarborgd wordt, is het gevoel echt te kunnen ontspannen niet te bereiken (Montano, 2015).

Een voorbeeld waarin ondersteuning van zowel fysieke als mentale gezondheid wel bereikt wordt, is de Reload Booth (afbeelding 7). De relax stoel biedt gelegenheid om een drukke dag te onderbreken en met herwonnen energie verder te kunnen werken terwijl tegelijkertijd een aantal (culturele) obstakels voor gebruik wordt verkleind (Rudzinska, 2022). Dit ontwerp is onderdeel van de kantooromgeving en niet gepositioneerd in een aparte kamer. De Reload Booth is akoestisch wel ontkoppeld door gebruik van geluiddempende materialen en de mogelijkheid tot gebruik van muziek. De stoel kan van actieve zithouding naar een meer achterovergebogen ontspannende houding gebracht kan worden, zodat met de laptop kan worden gewerkt, maar ook kan worden ontspannen. Door middel van ingebouwde sensoren in de zitting en rugleuning van de stoel worden de hartslag en de ademhaling gevolgd van de gebruiker (Zalar, 2022). Hiervoor zijn piezoelectrische en piezoresistieve sensoren toegepast die geprint zijn op een flexibele drager van TNO bij Holst Centre, zodat

Afbeelding 7. Reload Booth zoals geïnstalleerd op de WPVH. Ontwerp van Joanna Rudzinska (2022).

Afbeelding 8. Biofiele inrichting van de WPVH.

ze onmerkbaar in de stoel geïntegreerd zijn. Hiermee kan ook het effect van de Reload Booth direct aangetoond worden. Met deze informatie kan het programma van tijdsduur en intensiteit van massage en geluid aangepast worden. Ook wordt hiermee het effect gekwantificeerd zodat de gebruiker zelf het nut ervaart: ontspanning wordt zichtbaar door veranderde hartslag(variabiliteit) en ademhaling. Voor het positief veranderen van de cultuur in de werkomgeving is dit ook een belangrijk bewijs dat het investeren in (micro) breaks in plaats van continue fysieke en mentale belasting zowel welbevinden als verhoogde productie van de werknemer oplevert. Biofiele elementen in de inrichting van de kantooromgeving kunnen ook bijdragen aan het welbevinden van de werknemers (zie afbeelding 8).

Bijdrage aan het Human Factors-kennisdomein

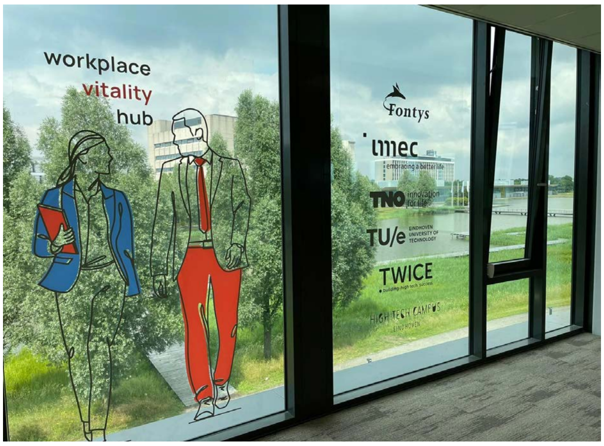
In de systeembenadering die binnen de WPVH toegepast wordt, worden in de kantooromgeving vitaliteitsvraagstukken behandeld vanuit verschillende disciplines, zoals bouwkunde, industrieel ontwerp, gedrags- en fysieke en mentale gezondheidswetenschappen ondersteund door datascience en technologie. Afhankelijk van het vraagstuk en de betrokken partners worden de systeemgrenzen aangepast van smal (bijvoorbeeld de ontwikkeling van een concreet product dat gecommercialiseerd of gevalideerd kan worden) tot aan een brede vraagstelling als bijvoorbeeld hoe in teams (werk)stress gemanaged kan worden. Voor het waarborgen van het zorgvuldig betrekken van invloeden buiten de vastgestelde systeemgrenzen worden in de community van de WPVH vakspecialisten buiten de betrokken disciplines geconsulteerd.
In de WPVH wordt de informatie die door en met de technologie verkregen wordt continue gebruikt om de behoeftes, mogelijkheden en beperkingen van de kantoormedewerker in kaart te brengen. Essentieel is de individuele feedbackloop waarin een aangebrachte interventie of systeemverandering gevolgd wordt via hetzelfde informatiekanaal, zodat effect en mogelijke additionele verbetering geïdentificeerd kan worden. Door ook op persoonlijk niveau te kijken kan geïndividualiseerd en gecontextualiseerd een oplossing geboden worden. Het onderzoek en de ontwikkeling in de WPVH richt zich op een combinatie van verhoogde productiviteit van werknemers en het verbeteren van welbevinden en werkgeluk. De verhoogde productiviteit wordt nagestreefd door geoptimaliseerde werkomgeving, bewustwording van werknemers en individuele coaching en feedback, hetzij rechtstreeks uit technologische informatiebronnen, hetzij (ondersteund door technologie) door sociale interactie. Het welbevinden van de werknemers wordt actief bereikt door het stimuleren van gezond gedrag door hulpmiddelen, sociale interactie en het verzorgen van optimale omstandigheden. De essentie van vitaliteit bevorderen is de koppeling tussen productiviteit en welbevinden, beiden zijn onlosmakelijk verbonden.

Conclusie

De Workplace Vitality Hub is een living lab-omgeving waarin vanuit multidisciplinaire programma's die vitaliteit bevorderd wordt door middel van technologie. Technologie wordt ingezet om informatie te verzamelen voor het ontwerp van interventies, het monitoren en valideren van de effectiviteit van interventies en het ondersteunen van een duurzame gedrags- en cultuurverandering die bijdragen aan een optimale werkomgeving. Samenwerking tussen kennis- en onderwijsinstellingen met externe partners zoals commerciële en publieke partijen is hierbij essentieel om technologische oplossingen naar de markt te brengen en in de praktijk geïmplementeerd te krijgen.

Summary

The workplace Vitality Hub is a living lab and initiative of Fontys Hogescholen, Technical University Eindhoven, imec-NL and TNO to develop and apply technology for vitality of office workers. Challenges in the research lines of physical and mental health, data in the office environment are accepted in a multidisciplinary approach. Technology serves to collect and generate information to invent solutions for improved vitality but also to validate those solutions and apply information in sustainable behaviour and cultural changes. A network of sensors is installed in the lab and tools to collect subjective data are being researched. The collaboration has led to insights in stimulation of physical activity and microbreaks by nudging and awareness of factors for physical and mental health. Examples of improved office furniture and environmental settings have been validated. A holistic approach including outdoor spacing, cultural aspects and biophilic design has proven successful for enhanced office vitality.



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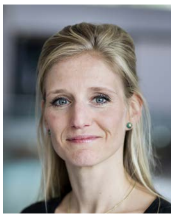
Over de auteurs

Margreet de Kok
Senior scientist/Project leader
TNO High Tech Industry
Holst Centre
Eindhoven
margreet.dekok@tno.nl

Ida Damen
Fontys Hogeschool
Eindhoven

Bernard Grundlehner
imec-NL
Holst Centre
Eindhoven

Eveline Kersten
Fontys Hogeschool
Eindhoven



Marieke van Beurden
Technische Universiteit
Eindhoven

De redactie stelt zich voor

Naam: Hetty Vermeulen
Functie: Human Factors Consultant
Werkgever: vhp
E-mail: hettyvermeulen@vhp.nl

Mijn naam is Hetty Vermeulen, senior adviseur bij vhp human performance. Met het schrijven van deze introductie realiseer ik me dat ik inmiddels al bijna 30 jaar in het vak zit: begonnen bij BGD Zwolle en omstreken, wat later Arbo Unie is geworden, en na 14 jaar de overstap gemaakt naar vhp, waar ik nog steeds met heel veel plezier werk.

Na mijn studie bewegingswetenschappen aan de RUG (wat alweer 100 jaar geleden lijkt) heb ik de PDBO Ergonomie bij Arbeid gedaan. Mijn drijfveer is een bijdrage leveren aan een veiliger en gezonder Nederland. Fysieke belasting is het thema waar je mij middenin de nacht voor wakker kunt maken. Laten we dat graag vooral figuurlijk houden trouwens.

In mijn werk ben ik oplossingsgericht, waarbij ik graag interne en externe expertise aan elkaar verbind en ook de samenwerking met andere expertisegebieden zeker niet uit de weg ga. Elkaar vanuit de verschillen versterken, om zo het beste resultaat voor de klant na te streven.

Ik ben een mensenmens met de overtuiging dat luisteren en begrijpen het uiteindelijke resultaat naar een hoger niveau brengen. Van de dynamiek die daarbij ontstaat in de samenwerking met collega's en klanten gaat mijn hart sneller kloppen!

Binnen de redactie van het *Tijdschrift voor Human Factors* ga ik mij voornamelijk bezighouden met de praktische toepassing van Human Factors/Ergonomie. Wetenschappelijk onderzoek is nodig en waanzinnig interessant. Maar hoe vindt nu de vertaalslag plaats naar de praktische toepasbaarheid van die inzichten?

O ja. Na op behoorlijk niveau te hebben gevolleybald, was hardlopen een makkelijke sport om met een gezin te combineren. Mijn passie voor bewegen heb ik dus al van jongs af aan. Met de paplepel ingegoten gekregen door mijn nu 80-jarige vader, die nog steeds bijna dagelijks zijn rondjes rijdt op de racefiets. Soms mag ik mee. En kan ik hem tegenwoordig net bijhouden!

Een goed begin en nog maar halverwege

De zomer staat weer voor de deur. Een mooi moment om stil te staan bij wat er in het eerste gedeelte van dit jaar binnen en rondom de verenging gebeurd is, en vooruit te blikken op wat 2024 nog voor ons in het verschiet heeft.

Op vrijdag 22 maart namen Jan Dul (Erasmus Universiteit) en Johan Molenbroek (TU Delft) het erelidmaatschap in ontvangst tijdens een goedbezochte en feestelijke bijeenkomst in Delft. De slides en foto's van deze bijzondere middag zijn te bekijken op de HFNL-website. In de volgende uitgave van het tijdschrift (september) volgt een verslag van de rondetafeldialogen die deze middag gehouden zijn rondom de thema's arbozorg en inclusive design.

De voorjaars-Algemene Ledenvergadering vond plaats op vrijdag 31 mei bij de Nederlandse Arbeidsinspectie in Utrecht. Voorafgaand aan de ALV gaf oud-bestuurslid Sander Vries een inkijkje in de werkzaamheden van de human factors specialisten bij de Arbeidsinspectie. De ALV gemist? Het jaarverslag 2023, het financieel jaarverslag 2023 en het advies van de kascommissie zijn te vinden op de HFNL-website.

Het Human Factors NL Jaarcongres zal dit jaar plaatsvinden op vrijdag 1 november bij de TU Eindhoven. Een locatie waar we erg blij mee zijn, want het is een universiteit waar veel gebeurt op het gebied van human factors. Aan de hand van het congresthema 'inclusie' onderzoeken we dit jaar hoe het vakgebied human factors kan bijdragen aan een inclusieve samenleving. De congreswebsite is inmiddels live en open voor registratie en het indienen van sessievoorstellen en individuele presentaties. Kijk op www.humanfactors.nl/congres. We hopen veel voorstellen van jullie te mogen ontvangen. Inzendingen voor de scriptieprijs zijn ook welkom. Deel de oproepen vooral ook buiten de vereniging.

Ook binnen de International Ergonomics Association (IEA) gebeurt veel. Het driejaarlijkse internationale congres van de IEA vindt komende zomer plaats in Jeju, Zuid-Korea. Voorafgaand aan het congres vindt de Council Meeting plaats waar ook HFNL-voorzitter Marijke Melles aan zal deelnemen. In deze meeting wordt onder andere gestemd over nieuwe IEA-bestuursleden en de locatie van het congres in 2030 (IEA2027 zal plaatsvinden in de UK). Daarnaast organiseert de IEA regelmatig webinars over uiteenlopende onderwerpen. Houd hiervoor de IEA-website in de gaten (www.iea.cc).

Dringende oproep

Als laatste een dringende oproep aan onze leden: de HFNL-website en het achterliggende content management system (CMS) zijn aan vernieuwing toe. Deze vernieuwing biedt ook kansen om eens goed na te denken hoe we ons als vereniging (digitaal) willen profileren. Het bestuur is zich hierop aan het oriënteren en wij zoeken één of twee leden die deze taak op zich willen nemen. Heb je interesse? Neem contact op met de secretaris van het bestuur, Pieter Coenen (secretaris@humanfactors.nl).

Namens het bestuur van Human Factors NL
Marijke Melles, Pieter Coenen, Reinier Hoftijzer en Wietske Eveleens