Facilitators and Barriers of Wearable Stress Management Technology: A Narrative Review of User Perspectives

Merel K. N. van den Berg
Interaction Design Group
University of Twente
Enschede, Netherlands
m.k.n.vandenberg@utwente.nl

Armağan Karahanoğlu
Interaction Design Group
University of Twente
Enschede, Netherlands
a.karahanoglu@utwente.nl

Matthijs L. Noordzij
Psychology, Health and Technology
University of Twente
Enschede, Netherlands
m.l.noordzij@utwente.nl

Els L. M. Maeckelberghe
Beatrix Children's Hospital
University Medical Center Groningen
Groningen, Netherlands
e.l.m.maeckelberghe@umcg.nl

Geke D. S. Ludden
Interaction Design Group
University of Twente
Enschede, Netherlands
g.d.s.ludden@utwente.nl

Abstract

Research and technological advancements have driven the development of wearable technology for stress management. Previous reviews primarily focused on its performance and effectiveness in health contexts. In contrast, this review takes a human-centric approach and reviews studies on users' attitudes and experiences. We conducted a narrative review to identify (1) the facilitators and barriers of wearable stress management technology (WSMT) and (2) design considerations for human-centered WSMT. We identified 28 articles reporting user perspectives on stress management technology, primarily based on evaluation studies in which user perspectives were gathered through qualitative methods. We found five facilitators and barriers of WSMT (i.e., usefulness, functionality/interactivity, seamlessness, user privacy, and technology's image). Additionally, we synthesized 18 design considerations, highlighted two main design challenges, and proposed a value-sensitive approach for future research. This review adds to the HCI literature by demonstrating the complexity of designing human-centered WSMT and the need for actionable recommendations.

CCS Concepts

• **Human-centered computing** → Human computer interaction (HCI); HCI theory, concepts and models; Interaction design; • **Applied computing** → Life and medical sciences; Consumer health.

Keywords

Stress Monitoring and Management, Wearable Technology, User Experience, Narrative Review

ACM Reference Format:
Merel K. N. van den Berg, Armağan Karahanoğlu, Matthijs L. Noordzij, Els L. M. Maeckelberghe, and Geke D. S. Ludden. 2025. Facilitators and Barriers of Wearable Stress Management Technology: A Narrative Review of User Perspectives. In *CHI Conference on Human Factors in Computing Systems (CHI '25), April 26–May 01, 2025, Yokohama, Japan*. ACM, New York, NY, USA, 24 pages. https://doi.org/10.1145/3706598.3713802

CHI '25, Yokohama, Japan

ACM ISBN 979-8-4007-1394-1/25/04
https://doi.org/10.1145/3706598.3713802

1 Introduction

Stress is a universal phenomenon affecting people's daily lives worldwide [7, 64]. Depending on its nature, stress can positively or negatively impact physical and mental health [9, 67]. Acute stress responses, which are the body's immediate reactions to a perceived threat or challenge, have a clear start and end [19] and can enhance physical and cognitive performance by activating adaptive mechanisms [16]. In contrast, chronic stress responses, which involve prolonged activation of these systems over time [19], can elevate the risk of mental health disorders [49, 65, 74] and cardiovascular diseases [16, 40, 50], which are among the leading causes of mortality [67]. Similarly, eustress, which arises when demanding situations are seen as challenging, results in excitement and healthy physiological states [9, 18, 69], while distress, which occurs when these situations are perceived as overwhelming [9, 18], contributes to negative health outcomes such as burnout [9] and cancer progression [85]. Yet, the distinction between eustress and distress is debated [5], as the effects of stress on health and performance are influenced by complex appraisal processes, such as those described more comprehensively in the threat/challenge hypothesis [34] and other models of stress, allostatic load, and coping [e.g., 19, 44]. Nevertheless, the prevalence and far-reaching consequences of chronic stress and distress in society, such as recurring workplace stress being a major contributor to employee absenteeism [7], have prompted the World Health Organization (WHO) to designate stress as the health epidemic of the 21st century [9].

Stress management techniques, ranging from simple breathing exercises to more complex techniques such as cognitive behavioral therapy [62] have been shown to reduce the adverse effects of stress, including chronic stress and distress [2, 10]. However, recognizing pathological stress levels and applying these techniques in a timely manner can be challenging [17]. Moreover, their effectiveness varies across individuals and it can be difficult to perceive immediate effects [83]. Advancements in wearable technology, such as the innovation of smartwatches and smart clothing, can offer innovative approaches to measuring stress indicators. Integrated wearable sensors can measure indicators of the stress response, i.e., the cognitive, emotional, and biological reactions associated with stress, such as an increased heart rate [19, 89]. Based on those indicators, wearables provide alternative ways of timely and personalized application of stress-relieving interventions, ranging from reminders to take breaks [e.g., 18] to calming vibrations [e.g., 38, 41]. Some wearable devices serve as stand-alone intervention tools, which initiate stress interventions such as breathing exercises directly through the device. Other wearable devices are extended through smartphone applications, allowing individuals to review their stress levels over time [e.g., 13, 42, 43, 81]. In this review, we will use the term *wearable stress management technology (WSMT)* to refer to wearable devices intended to support individuals with stress management, potentially but not necessarily linked to external devices such as smartphones.

Prior reviews have explored WSMT, focusing on physiological signals [e.g., 79], sensors [e.g., 33], prediction models [e.g., 24], and applications in specific domains [e.g., 55]. Although they yielded valuable overviews of the state-of-the-art and proof-of-concepts, their findings remained technology-centric and did not address users' experiences and needs. A recent scoping review [27] exclusively included studies that involved user evaluations, resulting in a corpus of 40 studies. This review identified three stress management techniques in the technology designs: self-regulation during stress episodes, stress prevention, and stress-regulation therapies. The authors concluded that wearable technology can help reduce stress, while there remains a need for comprehensive devices that integrate all three strategies. However, the studied outcomes in this review were limited to the impact of the technology on health and usability. Consequently, other factors affecting user acceptance and engagement with the technology, such as users' needs and concerns, were not identified.

Prior research demonstrated that user acceptance and engagement are crucial in the adoption and sustained use of wearable technology in daily life [12, 59]. Thus, a more nuanced and human-centric review is needed to better understand the facilitators and barriers to using and integrating wearable technology in stress management. Therefore, this paper studies prior work that addresses user perspectives on stress management technology, rather than solely evaluating its performance or efficacy in health management. In contrast to previous reviews that solely included evaluation studies [e.g., 27], we also incorporate studies focusing on the initial phases of human-centered design, such as understanding people's behaviors and contexts and specifying their problems and needs [28]. This way, we aim to identify how human-computer interaction (HCI) studies address these facilitators and barriers, i.e., the factors that enable (i.e., facilitators) or hinder (i.e., barriers) user engagement with the technology. Additionally, to gain a comprehensive understanding of the human experience with stress management tools—beyond mere monitoring—we focus on studies incorporating stress interventions. We aim to address the following research question (RQ):

> RQ: What facilitators and barriers of wearable stress management technology (WSMT) are reported in Human-Computer Interaction (HCI) research?

To address this research question, we adopt a narrative review approach to summarize the state of the knowledge and provide directions for future research and design. Our review has two primary contributions. Firstly, by zooming in on the studies that analyze users' attitudes and experiences – rather than those that predominantly evaluate technological performance – we reveal facilitators and barriers of WSMT. Secondly, we link these factors to existing design recommendations to establish design considerations to design for individuals' needs and concerns. This approach provides HCI researchers and designers with a coherent, integrated, and dedicated foundation for making responsible and human-centered design choices in designing WSMT. In the following sections, we will explain our methods, provide an overview of our corpus, and present and discuss our findings.

2 Method

In line with recommendations for narrative reviews [20], we used a structured approach for the literature search, drawing from the PRISMA Scoping Review guidelines (PRISMA-ScR) [77], which we will explain in the following lines.

2.1 Search Strategy and Keywords

We ran a search query in the following relevant academic databases: Scopus, ACM Digital Library, IEEE Xplore Digital Library, PubMed, and PsychInfo. Our query included (1) stress management and (2) wearable technology. For the former, we used terms such as "stress tracking", "stress regulation", and "stress feedback". For the latter, we used terms such as "smartwatch", "mobile sensors", and "Fitbit". The commercial device names used in the search string (e.g., "Fitbit") were selected based on frequently encountered device types and brands used in stress monitoring and management studies. We tailored the query to the specific databases and search engines. For instance, in Scopus we required "stress" to appear in the title to eliminate the large body of work where "stress" is used as a verb in the abstracts. We also scanned the references of the aforementioned scoping review [27]. Our last retrieval was on December 4, 2023. An example query (i.e., Scopus version) was as follows:

> **TITLE** (stress AND (*monitor* OR *manag* OR *track* OR *interven* OR *regulat* OR *aid* OR *cope* OR *coping* OR *improv* OR *reduc* OR *relie* OR *releas* OR *resist* OR *alleviat* OR *reflect* OR *feedback* OR *display*)) **AND TITLE-ABS-KEY** (wearable* OR smartwatch* OR "smart watch*" OR "sport* watch*" OR "fitness tracker*" OR "activity tracker*" OR fibit* OR empatica OR garmin OR wristband* OR *belt* OR "mobile sensor*" OR "smart clothing*" OR "smart textile*")

2.2 Selection Criteria and Corpus

To arrive at our final corpus, we first screened the titles and abstracts of the retrieved articles. If both appeared relevant, we proceeded to review the full texts of the articles against the inclusion and exclusion criteria. We included articles that met the following inclusion criteria: (1) the technology is designed for self-management of mental stress; (2) the technology involves both stress detection (including self-report) and intervention (including simple stress feedback); (3) technology includes a wearable device to be worn on the body; and (4) the article reports on users' perceptions and perspectives of the technology. We excluded articles that met the following exclusion criteria: (1) the recorded stress levels were only used by third parties (e.g., nurses), meaning no self-management was involved, and (2) the focus was on stress-related emotional states such as anxiety.

It is important to note that there is no universally accepted definition of wearable technology in the literature [14, 26]. Our search focused on technology designed to be worn on the body in a specified, consistent, and continuous manner (e.g., smartwatch) while excluding technology worn in a non-specified, inconsistent, and temporary manner (e.g., a phone held in a sports armband) [54]. Continuously worn technology is particularly promising for stress management in daily life, as it could enable continuous and unobtrusive stress monitoring.

Our search yielded 894 articles, which were reduced to 465 articles after duplicates were removed (see Figure 1). After applying the exclusion and inclusion criteria, we finalized a corpus of 28 articles. The majority of the articles (N=21) were identified through the Scopus query. One article meeting the criteria [39] – though not retrieved through any queries or related reviews due to the absence of wearable technology terms in the title, keywords, or abstract – was identified during a preliminary search. While the first author performed most of the article selection, other authors were frequently consulted to reduce potential bias.

2.3 Data Extraction and Analysis

The articles in our corpus provided us with three sources of information for our review: article characteristics, facilitators and barriers of WSMT, and design recommendations. We first extracted article characteristics to provide an overview of our corpus. Then, we applied thematic analysis to extract facilitators and barriers of WSMT. Finally, we synthesized design considerations from the findings of our corpus. We will explain our analysis process in the following lines.

Information Extraction: The first author extracted study characteristics from our corpus, including population samples, study methods, and technology used. These characteristics were categorized where possible (e.g., type of stress response measurements: physiological, behavioral, or self-reported). We report these findings in Section 3. We also extracted the design recommendations for WSMT that were based on the findings of the reported user studies (e.g., "Include a set of definitions of what stress is and how physiological and perceived stress levels can vary" [13]). We report these findings in Section 4.6 and Appendix A.2. To minimize bias in information extraction, the file with the extracted information was shared with all authors from the outset and the first and second authors engaged in ongoing discussions until all information was recorded.

Thematic Analysis: To identify the facilitators and barriers of WSMT, we analyzed user perspectives presented in the articles. We first uploaded all articles to Atlas.ti qualitative analysis software (Version 24). We then applied thematic analysis to analyze the relevant article content (i.e., primarily their results sections) inductively and deductively [8]. We followed the six phases of thematic analysis, as outlined below in italics and brackets (*Example)*. The thematic analysis was mostly carried out by the first author, regularly checking with the second author, while all authors contributed to the analysis process at various stages of the thematic analysis.

We first familiarized ourselves with the content of the articles by scanning through them (*Familiarization)*. Then, we conducted coding *(Coding)* to identify expressions of user perspectives with clear sentiment and reasoning (e.g., "[..] they valued a simple and logical design that was not too "overloaded" and used appealing colors" [39]). We excluded generic statements about the technology, neutral statements, features unrelated to stress management, authors' interpretations, envisioned implications, and organizational matters. For example, we excluded statements such as "Users were generally enthusiastic about the potential of a system like MoodWings" [47], as it was too generic. This process yielded 280 codes, some of which appeared in multiple articles.

Next, the first and second authors jointly reviewed a selection of codes to conceptualize the themes [8]. This process yielded several sub-themes of facilitators and barriers (e.g., informativeness and unobtrusiveness; *Generating initial themes)*. The first and second authors continued theme conceptualization for the remaining codes in ongoing discussions, assigning codes to existing sub-themes or creating new sub-themes. For each sub-theme, we agreed on a definition and adapted it when new codes led to an expanded understanding of the facilitator or barrier (*Developing and reviewing themes)*. The list of sub-themes was further refined in consultation with all authors, resulting in a final set of 15 sub-themes. We then grouped these sub-themes into five main themes *(Refining, defining, and naming themes)*. The names of the themes were not based on a specific taxonomy to avoid limiting our findings, except for themes related to usability [3]. After iterating and refining, we reported all findings in Section 4 *(Writing up)*.

***Synthesizing Design Considerations**:* To arrive at an integrated set of design considerations for WSMT, we first merged similar design recommendations that were extracted from the corpus (see *Information Extraction)*. Next, where applicable, we related these recommendations to evidence from the thematic analysis (see *Thematic Analysis)*. For instance, one of the extracted design recommendations, "[stress] feedback should come with transparent yet easy-to-understand explanations of the predictions" [39], was also substantiated by recommendations and findings in other articles of our corpus [13, 17]. Only considerations supported by at least two references were retained, resulting in 18 final design considerations, which were subsequently organized by five design features (e.g., stress interventions). We report these particular findings in Section 4.6.

2.4 Limitations

There are a few limitations in our article selection and data extraction method. First, due to the lack of uniformity in terminology related to stress, stress management, and wearable technology, our search might not have identified all relevant articles. Our search was concluded in December 2023, naturally excluding articles published after 2023.

In the article selection phase, we purposefully did not focus on a particular target group. Therefore, our corpus included articles that address both the general population and those that focus on specific populations (e.g., former military personnel with mental health disorders [46, 57, 84]). The differences in target user groups were not considered in the coding process and synthesis of design

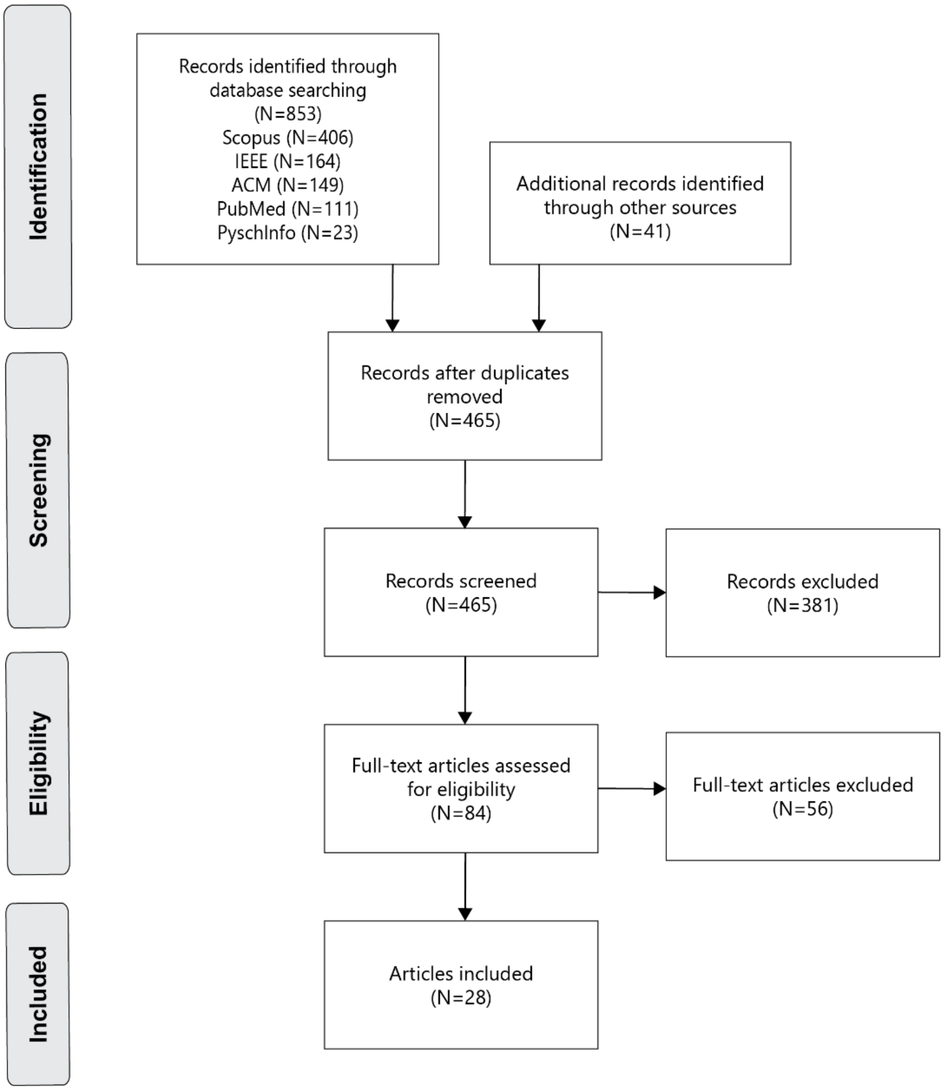

Figure 1: PRISMA Flow Diagram of Article Selection.

considerations. As a result, our design considerations stem from a mix of various target groups and may therefore be biased toward certain user groups. We aimed to reduce this bias by combining multiple references (at least two) per design consideration to extend the applicability of our findings to a broader range of contexts. Even though our results can to some extent be generalized across diverse user groups, our results should be interpreted carefully.

The set-up of the evaluation studies in our corpus determined which interaction aspects and use cases of the technology were highlighted. This inevitably steered the themes we conceptualized during the coding process. For instance, Adler et al. [1] specifically addressed data sharing and privacy, which ultimately became a theme in our analysis. Conversely, themes relevant to managing chronic stress or burnout are missing, as these conditions were not addressed in our corpus.

3 Characteristics of the corpus

Our corpus consists of 28 articles published between 2007 and 2023. They include both conference papers (N=16) and journal articles (N=12)[1]. An overview of all recorded study characteristics can be found in Appendix A.1.

3.1 Study Characteristics

We identified four study foci and various research methods that researchers used to collect user perspectives (see Table 1)[2]. Only nine articles reported user involvement in the design phase—before

---

[1] Both will be referred to as "articles" in the current review.

[2] It is possible that an article was associated with multiple sub-categories (e.g., because the authors conducted multiple studies).

Table 1: Study characteristics.

Main Category	Sub-Category	# of Articles	References
Main goal of the study	Evaluate users' experience with a mid-fi or hi-fi prototype	22	Lab evaluations (N=8): [13, 21, 38, 41, 47, 57, 76, 83] Field evaluations (N=14): [6, 18, 37, 42, 43, 45, 53, 57, 63, 68, 71, 81, 84, 86]
	Elicit requirements to inform the design of new technology before developing a prototype	6	[1, 18, 41, 46, 48, 58]
	Evaluate users' first impressions of a lo-fi prototype	5	[1, 37, 39, 57, 66]
	Investigate long-term users' attitudes	2	[17, 48]
Study method	Interview	17	[1, 13, 17, 18, 21, 37, 38, 42, 43, 45, 46, 48, 53, 57, 58, 71, 86]
	Questionnaire	16	[6, 13, 18, 38, 39, 41, 43, 45, 47, 57, 63, 66, 76, 81, 83, 84]
	Focus group	3	[18, 57, 66]
	Other	5	[13, 37, 38, 46, 58]
	Unclear	1	[68]
Number of participants[a]	<10	7	[1, 37, 38, 46, 57, 58, 68]
	10-19	12	[1, 6, 13, 17, 18, 21, 42, 47, 48, 63, 66, 76]
	20-49	8	[37, 41, 43, 45, 57, 71, 84, 86]
	50-100	3	[53, 81, 83]
	>200	1	[39]
Period of using the technology	<24 hours	9	[6, 13, 21, 38, 41, 47, 66, 68, 76]
	1 day -<1 month	10	[18, 37, 42, 43, 53, 57, 58, 63, 81, 86]
	1-3 months	1	[84]
	>3 months	2	[17, 71]
	Not applicable (no actual use of the technology)	3	[1, 39, 46]
	Not available	3	[45, 48, 83]

[a] These participants were the intended users of the technology

a prototype or end product was developed or tested[3]. The remaining articles (N=19) only reported user involvement in the evaluation phase of WSMT. Thirteen of the 28 articles provided design recommendations based on the findings of their user studies (see Appendix A.2).

Most articles used qualitative methods to capture user perspectives. The methods were dominated by interviews (N=17) and questionnaires (N=16), with eight studies employing multiple methods. Five articles (N=5) included multiple participant studies [1, 18, 37, 41, 57]. The initial studies typically focused on establishing requirements for prototype development, while the follow-up studies evaluated the resulting prototypes.

The articles reported participant studies involving participants from diverse age groups, populations, and genders. These studies were primarily conducted in Western countries, such as Switzerland [39] and Finland [38]. The highest reported number of participants was 241 [39] and the lowest number was three [46]. All participants were adults with varying average ages: from 18,54 years [45] to 54 years [46], sometimes with wide age ranges such as 18 to 61 years [81]. Some studies included significantly more male participants (e.g., (former) military personnel [46, 57, 84]) or females (e.g., homeless adolescent mothers [45]). Fourteen articles targeted specific user groups, such as (former) military personnel with mental health disorders [46, 57, 84] and hospital staff [1, 58, 66]. One article deliberately recruited participants facing socioeconomic challenges, i.e., homeless adolescent mothers [45].

The period during which participants used WSMT varied across the articles. The longest period of use was one college semester of 14 weeks [71], while eight studies involved use during a single session. There was no actual use of the technology in three articles [1, 39, 46] and three other articles did not report the duration of use [45, 48, 83].

3.2 Technology Characteristics

In the next three sections, we elaborate on the (1) devices used for stress management; (2) functions of devices in stress management; and (3) ways of measuring the stress response.

3.2.1 Devices Used for Stress Management. We found that 24 articles specified the wearable devices in their designs, whereas four articles used examples or hypothetical designs [1, 39, 46, 48]. The wearable devices that were explicitly mentioned included smartwatches (N=10), other wristbands (N=8), chest bands (N=7),

---

[3] Even though the majority of the articles evaluated a prototype for which users were not involved, most of those evaluations served as user-informed input for future designs.

Table 2: Technology characteristics.

Type of Stress Measurement	Sub-Category	# of Articles	References
Physiological (N=25)	Cardiac activity	18	[6, 13, 21, 37, 38, 41, 47, 53, 58, 63, 66, 68, 71, 76, 81, 83, 84, 86]
	Skin conductance	7	[41-43, 45, 47, 68, 84]
	Other	1	[53]
	Unspecified or unclear	4	[17, 39, 46, 48]
Behavioral (N=8)	Physical activity	3	[1, 58, 66]
	Other	2	[1, 18]
	Unspecified or unclear	4	[17, 39, 46, 48]
Self-report (N=13)	Single-item	5	[6, 45, 57, 63, 81]
	Multi-item	2	[13, 42]
	Unspecified or unclear	6	[1, 17, 39, 46, 48, 84]

ankle-worn bands (N=1), ear clips (N=1), smart sleeves (N=1), and footwear sensors (N=1). Some articles involved multiple wearable devices, but most used or specified only one type (N=16).

In the majority of the articles (N=19), the wearable device was accompanied by a smartphone, tablet, or other type of external display, although they were not always defined (e.g., "dashboard" in [1]). These displays were often used to visualize stress indicators over time and adjust the technology's settings. Sometimes (N=5) displays also contained contextual information such as locations [63], timestamps [76], self-reported activities [63, 81], and calendar information [42, 43]. Graphical user interfaces were often personal, directed at a single user (N=16), whereas three articles used shared displays: two for work contexts [1, 86] and one for supporting close others [37].

3.2.2 Functions of Devices in Stress Management. We identified three functions of the wearable device in stress management: (1) measurement device (N=19); (2) intervention device (N=3); and (3) a combination of the two (N=11). Wearable devices that served as measurement devices were often accompanied by a smartphone, tablet, or other external display (N=14) to present the measured data. Intervention devices were intended either to raise awareness of the user's stress level [47] or to calm the user through soothing sensations [38, 41]. Wearable devices that were both measurement and intervention devices were all smartwatches (N=11). Most stress interventions were directed at immediate stress awareness (e.g., stress notifications [17, 18, 39, 45-47, 84]) or immediate stress relief (e.g., breathing exercises [48, 53, 57, 71, 84]). Articles that focused on longer-term stress awareness (N=9) often did not integrate direct stress interventions, but their stress visualizations aimed to provide individuals with insight into their stress patterns [1, 13, 42, 43, 58, 63, 68, 81, 86].

We observed a difference in WSMT characteristics between WSMT designed for the "general population" and groups facing significant stress-related challenges (i.e., former military personnel with mental health disorders [46, 57, 84] and homeless adolescent mothers [45]). The former primarily provided fine-grained stress visualizations and simple stress-relief exercises or stress-relieving haptic sensations. The latter primarily provided stress notifications as warning signs and assisted users in coping behaviors by encouraging them to apply skills learned in therapy.

3.2.3 Ways of Measuring the Stress Response. There were three types of stress response measurements in our corpus: physiological, self-reported, and behavioral (see Table 2). One article [46] did not specify stress measurements, as the research was indicated to be exploratory and involved conceptual design of the technology.

The majority of the articles (N=25) employed wearable devices that measured physiological signals as indicators of the stress response. Eighteen articles used cardiac activity (including heart rate variability, HRV) and seven used skin conductance (EDA), with four articles using both. One article used particular measurements of brain activity (EEG) [53]. Two articles incorporated accelerometer data to correct physiological measurements affected by interfering motion [63, 86], while two other articles integrated accelerometer data into visual stress displays to contextualize the physiological stress measurements [21, 68]. Four articles were unclear regarding the physiological measurements, for instance when the authors studied consumer devices such as Fitbit and Garmin smartwatches but did not specify the metrics these devices used [17, 48].

Eight articles used behavioral measurements to measure the stress response, including physical activity [1, 58, 66]. These were often combined with physiological (N=6), self-reported measurements (N=5), or both (N=4), whereas one article only used behavioral measurements: foot posture and movement [18].

Thirteen articles used self-reported measurements to assess the stress responses, mostly in addition to physiological measurements (N=11). The self-reporting formats varied from simple sliders [45, 81] to multi-item questionnaires [13, 42]. Overall, the technologies in our corpus focused on momentary assessments or daily evaluations, while Chianella et al. [13] employed a questionnaire that assessed individuals' feelings over the last month. In four articles, self-report prompts were triggered when physiological stress response levels exceeded a certain threshold [45, 63, 81, 84]. Four articles did not integrate self-reports into interactions with the technology, meaning that the technology did not provide feedback nor allowed users to revise their historical stress levels [6, 42, 57, 84],

Table 3: Main facilitators and their descriptions.

Main Facilitator	Description of the Main Facilitator	# of Articles	Sub-Facilitator
Usefulness	User perspectives on the technology's usefulness and effectiveness in stress management	25	Helpfulness Informativeness Calmingness
Functionality/ Interactivity	User perspectives on functional aspects of the technology and interactions	16	Ease of use Clarity (Perceived) Data accuracy Adaptiveness Controllability
Seamlessness	User perspectives on the ease of integrating the technology into daily life	12	Integration into daily life Comfortability in wear Unobtrusiveness
User Privacy	User perspectives on sharing information with others	9	Data privacy Discretion
Technology's Image	User perspectives on the technology's appearance and traits	7	Anthropomorphic attributions Aesthetics

Table 4: Three sub-facilitators of usefulness.

Name of the Sub-Facilitator	Description of the Sub-Facilitator	# of Articles	References
Helpfulness	Extent to which the technology helps users deal with stress	21	[1, 13, 17, 18, 21, 37, 39, 42, 43, 45-48, 53, 57, 58, 66, 68, 71, 76, 86]
Informativeness	Extent to which technology provides comprehensive and useful information	19	[1, 6, 13, 17, 18, 21, 37, 39, 42, 43, 45, 46, 53, 58, 68, 71, 76, 81, 86]
Calmingness	Extent to which the technology reduces users' tension and makes users feel relaxed	5	[38, 41, 48, 53, 71]

leaving only nine articles that integrated self-reporting stress in their designs [1, 13, 17, 39, 45, 46, 48, 63, 81].

The articles varied not only in the types of stress response measurements but also in their perspectives on stress, emphasizing various aspects and interpretations of the concept. Thirteen articles explored specific manifestations of stress, including PTSD [46, 57], a clinical diagnosis, and work-related stress [1, 18, 39, 48, 58, 66, 86], which refers to stress experienced in occupational settings. Notably, half of the articles in our corpus did not clearly define stress and the majority (N=23) did not distinguish between different forms of stress, stressors, or stress responses, despite substantial variation in these phenomena [19]. Only three articles explicitly differentiated between acute stress and chronic stress [18, 21, 38] and only three articles differentiated between eustress and distress [17, 18, 81].

4 Facilitators and barriers of wearable stress management technology

We found five main themes that facilitate the use of WSMT: usefulness, functionality/interactivity, seamlessness, user privacy, and technology's image, as well as various sub-themes belonging to them (e.g., helpfulness; see Table 3). From this point forward, we will call the main themes "facilitators" and sub-themes "sub-facilitators" for the sake of understandability of the results, while (sub-)facilitators might also act as a barrier. In the following subsections, we will describe each facilitator and their accompanying sub-facilitators. As mentioned in Section 2.3, for themes related to usability, we used the taxonomy by Alonso-Ríos et al. [6].

4.1 Usefulness

Usefulness relates to how useful and effective users find the technology in stress management. It consists of three sub-facilitators: helpfulness, informativeness, and calmingness (see Table 4).

Helpfulness (N=21) is the extent to which the technology helps users deal with stress (see Table 4). Generally, there is interest in reviewing stress-related measurements and using them to gain insights into stress levels [13, 18, 21, 48, 58, 68]. Stress measurements provide individuals with insights into their stressors and help them understand which activities cause (physiological) stress [42, 43, 68, 81, 86]. These insights either confirm their expectations

Table 5: Five sub-facilitators of functionality/interactivity.

Name of the Sub-Facilitator	Description of the Sub-Facilitator	# of Articles	References
Ease of use	Extent to which interaction with the technology is effortless	6	[37, 53, 57, 71, 83, 86]
Clarity	"Ease with which the system can be perceived by the mind and the senses" [3]	6	[17, 38, 39, 45, 68, 86]
(Perceived) Data accuracy	Extent to which stress response measurements are perceived as correct	6	[1, 17, 18, 42, 45, 86]
Adaptiveness	"Capacity of the system to adapt itself to user preferences and to different types of environments" [3]	4	[39, 45, 48, 63]
Controllability	"Capacity of the system to permit users to choose the most appropriate way to use the system" [3]	3	[18, 39, 57]

[17, 18, 43] or strike them as "eye-openers" [42, 43, 58], which motivate individuals to reconsider their habits [37, 42, 86] and make positive lifestyle changes to manage stress [43, 48]. Furthermore, individuals suggest the potential of sharing their stress measurements with others (e.g., therapists [46], managers [1], and close friends [37]) so that others can support them better.

However, WSMT sometimes does not help or even hinders stress management. For instance, feeling overwhelmed by a stressful task typically leads to focusing on that particular task, rather than the technology, restricting its helpfulness [17, 21]. Additionally, stress feedback sometimes only reflects what individuals already know about their stress levels, which they find disappointing or frustrating [42, 43, 68, 81, 86]. Even when stress feedback provides new insights, it is not always helpful in dealing with or alleviating stress [17, 18, 43], for instance when stress is inherent to a profession and thus cannot be reduced [43]. Moreover, confrontation with high stress levels can form an additional stressor [42, 86].

Notifications of high stress levels are generally considered useful [1, 43, 45], particularly when these notifications show well-balanced sensitivity in responding to detected stress [45]. However, receiving stress notifications can be irritating when one is feeling stressed [13, 47, 48, 86]. Combining stress notifications with stress interventions, such as playing relaxing music [17] or initiating a breathing exercise [71], can increase their helpfulness. Custom and adapted stress interventions such as personalized reminders are particularly appreciated [18, 48]. Individuals also appreciate stand-alone reminders for stress interventions (i.e., reminders not necessarily linked to detected stress levels [39, 57]). However, there are concerns that stress interventions may be distracting, fail to address the root cause, and replace personal sensitivity to stress and the ability to self-manage stress [39]. Some individuals, when experiencing stress, prefer to address the underlying cause rather than use the technology to alleviate it [17].

Informativeness (N=19) is the extent to which technology provides comprehensive and useful information (see Table 4). As mentioned in Section 3.2.2, some technologies were designed to provide users with insight into their stress levels to increase (long-term) stress awareness. Detailed and comprehensive stress data presentations are generally preferred, both for real-time [21, 46] and historical [58] data. Accordingly, the time range of stress response visualizations should be sufficiently wide-ranging to discern fluctuations in stress levels over time (i.e., both covering the onset of and recovery from stress responses) [21, 68]. Additionally, the visualizations should contain reference ranges that distinguish "normal" from divergent stress levels [1, 17]. Enriching the physiological and behavioral data with contextual information, such as self-reported context [1], calendar information [18], location information [37, 68, 76], and health-related data from other applications [39], can enhance individual and group reflection [1, 18, 21, 37, 68].

Calmingness (N=5) is the extent to which the technology reduces users' tension and makes users feel relaxed (see Table 4). As highlighted in Section 3.2.2, some technologies were designed with the goal of (immediate) stress relief. Calming breathing exercises can alleviate stress, both in the form of guided sessions on consumer smartwatches [48] and bio- and neurofeedback training with ECG and EEG sensors [53]. Haptic soothing sensations can also have calming effects [38, 41].

4.2 Functionality/Interactivity

We bundled functionality and interactivity together, as they are inseparable when discussing the functional aspects of the technology and interactions. This facilitator consists of five sub-facilitators: ease of use, clarity, (perceived) data accuracy, adaptiveness, and controllability (see Table 5).

Ease of Use (N=6) is the extent to which interaction with the technology is effortless (see Table 5). Ease of use is facilitated through quick accessibility of wearable and mobile formats [1, 13, 39], while it might be compromised by small screens, especially for those with fine motor deficits [57], or sketchpad interfaces [37]. Ease of use might also be compromised when individual devices seem disconnected [6] or when wearable sensors have technical issues [53].

Clarity (N=6) is "the ease with which the system can be perceived by the mind and the senses" [3] (see Table 5). Individuals' preferences consist of an intuitive interface [39], understandable settings [39], and use of meaningful colors (i.e., green as "good" and red as "bad") [86]. Clarity may be compromised due to uncertainty regarding the technology's status, such as not knowing whether the device is charged and working properly [39]. If WSMT

Table 6: Three sub-facilitators of seamlessness.

Name of the Sub-Facilitator	Description of the Sub-Facilitator	# of Articles	References
Integration into daily life	Extent to which the technology fits into users' current lifestyles	7	[1, 37, 39, 45, 58, 66, 83]
Comfortability in wear	Degree of physical comfort users experience while wearing the technology	5	[18, 21, 42, 45, 58]
Unobtrusiveness	Extent to which the technology functions effectively without interrupting or disrupting users' daily activities and demanding users' attention unwantedly	4	[37-39, 86]

presents stress "scores" (i.e., physiological stress response measurements converted into numerical scores), these should be explained to bridge the gap between individuals' notion of stress and the physiological measurements of their devices [17].

(Perceived) Data accuracy (N=6) is the extent to which stress response measurements are perceived to be correct (see Table 5). Individuals are sometimes surprised when technology correctly identifies a stressful moment [45, 86]. Some individuals increasingly agree with presented stress level visualizations over time, suggesting that a period of familiarization with the data display is needed [86]. Stressful moments (i.e., peaks in stress levels) and moments of absence (i.e., data gaps when the measurement device is disconnected) serve as indicators of data accuracy in such visualizations [86]. Individuals' agreement with the correctness of the stress "scores" increases their willingness to engage with data [86], whereas a strong mismatch between measured and experienced stress leads to confusion [17] and disengagement [86]. Individuals are disappointed when not receiving a stress notification when feeling stressed, despite the technology's promises [17, 45]. To increase the validity of stress measurements, passively collected data could be enriched with self-reports and individual baselines [1]. Such baselines might be difficult to establish, as individuals might already suffer from chronic stress [1].

Adaptiveness (N=4) is "the capacity of the system to adapt itself to user preferences and to different types of environments" [3] (see Table 5). Stress interventions preferably match individuals' current state (e.g., affective state) and situation (e.g., at work) [45, 48]. For example, reflecting on mood can be useful when individuals are stressed, but annoying when individuals are in a good mood [45]. Conversely, some individuals dislike being interrupted when feeling stressed and prefer the timing of stress self-reports to be random [63].

Controllability (N=3) is "the capacity of the system to permit users to choose the most appropriate way to use the system" [3] (see Table 5). Individuals prefer the following ways of controllability: the option to change settings [39, 57], snooze or deactivate the system [18, 39], select preferred stress management interventions [18, 39], and customize stress thresholds (i.e., the level of detected stress before an intervention is triggered) [18].

4.3 Seamlessness

Seamlessness refers to the ease of integrating the technology into daily life. This facilitator consists of three sub-facilitators: integration into daily life, comfortability in wear, and unobtrusiveness (see Table 6).

Integration into daily life (N=7) is the extent to which the technology fits into users' current lifestyles (see Table 6). To facilitate seamless interactions, WSMT should be integrated with hardware and software that individuals already possess, such as their smartwatches [39] and messaging apps [37]. Furthermore, interactions with WSMT should align with individuals' lifestyles, including their work [58, 66] and daily routines [45], and should not be too burdensome [1]. Finally, considerations should include the accessibility of wearable technology, such as the high costs of biosensors [1, 83], as accessibility issues can also pose barriers to integrating WSMT into daily life.

Comfortability in Wear (N=5) is the degree of physical comfort users experience while wearing the technology (see Table 6). Wristbands are considered comfortable when the sensation of wearing them becomes unnoticeable [45] and uncomfortable when they are experienced as itchy and bulky [21, 45]. Chest bands are generally considered uncomfortable [21, 42, 58]; an alternative could involve integrating the chest-worn sensor into ordinary clothing, such as a bra, to enhance physical comfort [58]. A shoe-worn sensor is experienced as easy and comfortable to wear, often leading individuals to forget they are wearing it [18].

Unobtrusiveness (N=4) is the extent to which the technology functions effectively without interrupting or disrupting users' daily activities and demanding users' attention unwantedly (see Table 6). For instance, individuals worry that stress interventions may be distracting [39]. Haptic patterns of a smart sleeve are not found disturbing during a stressful task [38]. A non-disturbing communication design, which does not entail notifications or requires immediate replies, is appreciated [37].

4.4 User Privacy

User privacy informs us about user perspectives on sharing information with others. This facilitator consists of two sub-facilitators: data privacy and discretion (see Table 7).

Data privacy (N=6) is the extent to which the technology allows users to control which personal data they share, and with whom (see Table 7). Stress-related data are considered sensitive [1, 13, 39] and require establishing appropriate ways of sharing [1]. However, some individuals are completely at ease with physiological data

Table 7: Two sub-facilitators of user privacy.

Name of the Sub-Facilitator	Description of the Sub-Facilitator	# of Articles	References
Data privacy	Extent to which the technology allows users to control which personal data they share, and with whom	6	[1, 13, 37, 39, 42, 86]
Discretion	Extent to which the technology can be worn and used without drawing attention from others; an implicit form of anonymity	4	[39, 45-47]

Table 8: Two sub-facilitators of technology's image.

Name of the Sub-Facilitator	Description of the Sub-Facilitator	# of Articles	References
Anthropomorphic attributions	Human-like characteristics assigned to the technology or interactions	4	[18, 45, 46, 63]
Aesthetics	The technology's look, appearance	3	[21, 37, 39]

being recorded and shared with their supervisors [1]. Privacy sensitivity differs per device: cameras for facial analysis are considered more privacy-violating than wrist-worn stress detection devices [39, 42]. Privacy sensitivity also depends on with whom the data are shared: some individuals are willing to share their data only with close others and not with strangers [86], whereas others are uncomfortable sharing their data with familiar others [13], such as their managers [1] or colleagues [86]. Instead of automatic stress data sharing, individuals prefer to maintain control over the shared data to maintain the right to self-presentation [1, 37]. Furthermore, individuals want to know where their data are stored and how unauthorized access is prevented, for instance by storing at a known and certified external company [46, 47]. Some individuals worry that anonymizing data is difficult, as personal data often remain inferable [1].

Discretion (N=4) is the extent to which the technology can be worn or used without drawing attention from others, which can be regarded as an implicit form of anonymity (see Table 7). Overall, an unnoticeable stress-monitoring device is preferred to prevent others from realizing that individuals are using WSMT [39], which may lead to feelings of embarrassment [45]. Similarly, some individuals prefer quiet and private stress notifications to avoid drawing attention from others and revealing their affective state [46, 47].

4.5 Technology's Image

Technology's image refers to user opinions about the technology's appearance and traits. This facilitator consists of two sub-facilitators: anthropomorphic attributions and aesthetics (see Table 8).

Anthropomorphic attributions (N=4) are human-like characteristics assigned to the technology or interactions (see Table 8). WSMT is considered caring when it asks users how they are doing [45] and reminds them to take breaks when feeling stressed [18]. Individuals generally prefer WSMT that communicates in an empathetic manner (e.g., responding sympathetically [63]) [46, 63]. Strong and firm communication styles (e.g., loud warning sounds and haptic vibrations) can sometimes help to convey a need for action [46]. To be considered respectful, WSMT should consider users' limits, respect their values, and allow them to make their own decisions [46].

Aesthetics (N=3) refers to the technology's look and appearance (see Table 8). Individuals prefer WSMT with simple, balanced, and clear interface designs [21, 39] that feature appealing colors [39]. Specifically, simple and straightforward representations of stress levels (e.g., sea creature avatars that sink into the sea when stress levels increase [37]) are preferred over fine-grained bar charts of consumer smartwatches [37].

4.6 Design Considerations for WSMT

As we described in Section 2.3, we synthesized design considerations for WSMT from two sources of information: (1) design recommendations listed in articles of our corpus and (2) evidence from the thematic analysis (see Sections 4.1-4.5). We identified 56 design recommendations reported in the articles in our corpus (see Appendix A.2). A large share of the recommendations regarded general interaction design principles, such as intuitiveness of the interface [39], comfort of the wearable devices [38], and minimal data collection [39]. We discovered that the provided design recommendations were often generic and lacked concrete guidance, such as the recommendation to make the interface ”understandable” [39]. Some recommendations were more specific yet lacked actionable details, such as advising that self-report prompts should not interrupt current activities [46], without explaining how to achieve this. Still, to provide corpus-wide recommendations, as we explained in Section 2.3, we organized these 56 design recommendations into 18 design considerations (DeCos), which we finally categorized into five design features: (1) reviewing stress responses; (2) stress notifications; (3) data recording, storing, and sharing; (4) stress interventions; and (5) device aspects. In addition, we integrated related (sub)-facilitators in brackets (e.g., informativeness; see Table 9). We will report the design considerations per design feature in the following lines.

For **reviewing stress responses**, we found that overviews must be accurate, clear, and informative. This includes providing historical overviews (DeCo5), integrating contextual information (DeCo1), and distinguishing different levels of stress (DeCo4). For instance,

Table 9: Design considerations for WSMT.

Design Feature	Design Consideration	References
Reviewing stress responses (N = 13 articles)	DeCo1. Integration of contextual information that helps to contextualize stress responses and recognize stressors **(informativeness)**	[1, 13, 18, 21, 42, 43, 68, 76]
	DeCo2. (Indications of) validity and reliability of physiological stress response measurements **(data accuracy)**	[17, 39, 45, 86]
	DeCo3. Clear explanations behind stress response measurements, calculations, and predictions **(clarity)**	[13, 17, 39]
	DeCo4. (Visual) distinction between high stress levels and "normal" stress levels **(informativeness)**	[1, 17, 86]
	DeCo5. Historical overviews of stress responses **(informativeness)**	[18, 68]
Stress notifications (N = 7 articles)	DeCo6. Appropriate timing of stress notifications (i.e., adapted to personal preferences) **(controllability, unobtrusiveness)**	[17, 37, 45, 46]
	DeCo7. Appropriate number of stress notifications, well-balanced sensitivity to stress **(adaptiveness)**	[45, 63]
	DeCo8. Control over stress notifications, option to turn off stress notifications **(controllability)**	[17, 39]
	DeCo9. Discreet ways of delivering stress notifications **(discretion)**	[46, 47]
Data recording, storage, and sharing (N=6 articles)	DeCo10**.** Control over what data are shared with whom **(data privacy)**	[1, 39, 86]
	DeCo11. Control over passive data collection, option to stop passive data recording **(data privacy)**	[1, 39]
	DeCo12. Nuanced stress response assessments by combining passively collected stress measurements with self-reports **(informativeness, data accuracy)**	[1, 13]
	DeCo13. Option to easily share stress levels with others who can support (i.e., close others and therapist) **(helpfulness)**	[37, 46]
Stress interventions (N=6 articles)	DeCo14. Match between stress intervention and user's state, situational context, and type of stress **(adaptiveness, helpfulness)**	[18, 39, 45]
	DeCo15. Integration of calming breathing exercises **(calmingness)**	[48, 53]
	DeCo16. Integration of reminders to do stress relief activities **(helpfulness)**	[39, 57]
Device aspects (N =8 articles)	DeCo17. Easy and comfortable to wear **(comfortability in wear)**	[18, 21, 38, 42, 45, 58]
	DeCo18. Discreet look of wearable device, low noticeability of wearable device **(discretion)**	[39, 45, 47]

Kocielnik and Sidorova [43] provide weekly calendar views that display stress response measurements along a work calendar, so that stressful work activities can be detected. Furthermore, it should be clear how stress "scores" are calculated (DeCo3), for instance by explaining heart rate variability and the factors influencing it [17].

For effective and acceptable **stress notifications**, the number and timing of these notifications need to be adapted to individuals' needs (DeCo6). For instance, some individuals prefer to receive early notifications of increases in stress levels as they can serve as "warning signs" before they lose their temper [45, 46]. Yet, as receiving too many stress notifications can be irritating [45, 63], stress notifications should only be triggered when there is a significant change in stress levels (DeCo7). Individuals who perceive receiving a stress notification during a stressful moment as annoying should be able to disable the stress notifications (DeCo8). Additionally, the technology should provide discreet methods for delivering stress notifications (DeCo9), such as gentle contractions of a bracelet [46].

Regarding **data recording, storing, and sharing**, users should have control over what data is recorded (DeCo11) and shared (DeCo10). For instance, some individuals associate automatic data sharing with "the feeling of being monitored" and thus prefer manual data sharing [37]. Asking for self-reported stress levels can allow individuals to provide a nuanced representation of their stress responses (DeCo12). For instance, Chianella et al. [13] present a smartphone app that allows users to compare physiological data measured by a smartwatch with subjective stress measurements gathered through smartphone-based questionnaires.

Due to the primary focus of our corpus (i.e., immediate stress awareness or stress relief), design considerations regarding **stress interventions** mostly regard short-term interventions. The technology should offer ways to relieve stress, such as breathing exercises (DeCo15) and general reminders to practice stress relief activities (DeCo16). For instance, the stress management application of Morris and Wallace [57] prompts individuals to do a stress relief exercise when it detects heightened stress levels. Furthermore, interventions should match the type of stressor experienced (DeCo14). For instance, when experiencing eustress at work, individuals prefer interventions that increase their concentration, such as muting notifications. Contrarily, when experiencing distress at work, individuals prefer interventions that distract them from the source of their stress, such as coffee breaks [18].

Finally, there are two **device aspects** that require consideration: designing for wearability (DeCo17) and discretion (DeCo18). For instance, wrist-worn devices are generally more comfortable than chest-worn devices [42] and devices that can be integrated into ordinary clothing are preferable [18, 58]. Furthermore, the look of the wearable device should be discreet, for instance by minimizing its visibility [45].

5 Discussion

In this review, we focused on the human-centered aspects of WSMT by analyzing 28 articles that explore users' attitudes and experiences with WSMT. Our objectives were to (1) identify facilitators and barriers to WSMT use and (2) establish design considerations to guide human-centered design of this technology. Our results helped us answer the research question ("What facilitators and barriers of WSMT are reported in HCI research?"; see Section 4). In this section, we will discuss the broader implications of our results and closely examine the complexities of developing WSMT. Furthermore, we will highlight future research and design directions for WSMT.

5.1 Methods and Methodologies Used for Wearable Stress Management Technology in HCI Studies

We identified three points of attention in the methods and methodologies that were used in our corpus: user involvement, user diversity, and stress response measurement.

As mentioned in Section 3.1, a minority of articles in our corpus (N=9) reported user involvement in the design phase of the technology, before prototype development or testing. Meanwhile, one article highlighted that users of commercial WSMT lacked the fundamental knowledge to comprehend the provided stress feedback, which led to user disengagement [17]. Increased user involvement early in the design process could help prevent such disengagement by assessing end-users' knowledge levels. This aligns with core Human-Centered Design principles, emphasizing the importance of deeply understanding the target users during the initial design phases [51]. For WSMT, these phases should involve assessing users' stress literacy levels to design comprehensible stress feedback. As such, we recommend that future work prioritizes this approach to ensure the efficacy of the technology.

Participant studies in our corpus were predominantly carried out in Western countries and only one study intentionally recruited participants facing socioeconomic challenges [45] (see Section 3.1). The overrepresentation of wealthier groups suggests that the design and implementation of WSMT may be biased towards wealthy and health-literate groups, potentially neglecting the needs and challenges of socioeconomically disadvantaged groups. This highlights a critical concern because health tracking tools are known to risk reinforcing existing inequalities [82]. For instance, Veinot et al. [78] demonstrate how the current design of digital health interventions tends to be more effective for those who are socioeconomically advantaged. In contrast, individuals with lower socioeconomic status often face more contextual challenges associated with chronic stress (e.g., financial challenges and discrimination) and are more likely to engage in health-impairing behaviors linked to stress [4]. While WSMT may not directly address these stress-inducing factors, it could still offer benefits in such conditions. For instance, Leonard et al. [45] reported how WSMT assisted homeless adolescent mothers in employing more adaptive behaviors during stressful situations. Future research must investigate the specific stressors and behaviors associated with socioeconomically disadvantaged groups by actively recruiting these groups in WSMT research. This involves designing WSMT features that address their unique stress-related challenges and ensuring that the technology is accessible and usable for individuals with varying levels of health literacy.

Articles in our corpus employed various ways to measure stress responses, often lacking a clear definition of stress or stress responses. Moreover, most studies that used physiological stress measurements did not differentiate between different types of stress, i.e., acute and chronic stress and eustress and distress (see Section 3.2.3). Although the distinction between the latter is debated (see Section 1), the lack of stress type distinctions in our corpus suggests a potential gap in tailoring stress interventions to individuals' needs. For instance, Elvitigala et al. [18] found that participants preferred minimizing distractions when experiencing eustress and planning distractions when experiencing distress. Additionally, the detrimental effects of chronic stress on health [e.g., 67] highlight the need for more persuasive and impactful interventions compared to those for acute stress. Nevertheless, distinctions between interventions for acute and chronic stress interventions remain uncommon and other literature reviews on WSMT echo this [e.g., 27]. Combined with the primary focus of our corpus on short-term instead of long-term stress interventions (see Section 3.2.2), this highlights a gap in understanding how to design for long-term, sustainable stress reduction. Future research should explore distinctions between different stress types to develop more suitable, adapted stress interventions that enhance WSMT's effectiveness.

While articles in our corpus indicated that WSMT users valued reflecting on their subjective experience of stress [13, 17], only nine articles integrated self-reporting in their designs (see Section 3.2.3). This implies a gap in the current design of WSMT, which does not leverage stress self-reports to enhance user engagement. Consistent with the principles of stress reduction therapies [e.g., 61] we emphasize the importance of interoception in helping individuals connect with their bodily experiences of stress. Additionally, the complex relationship between physiological indicators and subjective experiences of affective states [30] complicates the identification of affective states when relying solely on physiological data. Hence, a multidimensional approach to stress assessment is essential in a way that extends beyond sensor-based stress data alone. Self-reports can complement passive sensing by correctly labeling stress responses, thereby improving the accuracy of stress detection and enhancing users' trust in the technology [54]. Future research should explore how best to combine objective and subjective methods of stress response measurements. To achieve this, HCI studies should tackle a multidisciplinary research approach to stress response assessment to create more effective and human-centered stress management technologies.

5.2 Addressing the Complexity of Designing Wearable Stress Management Technology

Our results indicate that designing human-centered WSMT is complex due to three reasons: (1) facilitators being prerequisites for other facilitators; (2) facilitators conflicting with other facilitators; and (3) personal preferences.

First, some facilitators described in Section 4 served as prerequisites for others. For instance, individuals using WSMT tend to take action to reduce their stress (i.e., helpfulness) only once they acknowledge the correctness of the stress feedback (i.e., perceived data accuracy) [17, 86] (see Section 4.1 and 4.2). Such prerequisites suggest a hierarchy of facilitators for WSMT, as well as the existence of fundamental criteria for user engagement. Interestingly, factors such as perceived data accuracy are not typically included in existing frameworks such as technology acceptance models [31] or usability taxonomies [3], although they appear particularly relevant to health tracking [e.g., 12, 52]. This indicates that WSMT, and health tracking technology in general, may have unique criteria for user acceptance and engagement. However, retrieving these criteria could be challenging, as criteria for adopting health trackers can vary significantly across individuals [70]. Future research should explore the adoption of WSMT to identify different stages and prerequisites that can inform effective design choices.

Second, some facilitators *conflicted* with others. For instance, individuals who are willing to enrich their stress response data with self-reports to provide a complete picture (i.e., informativeness and data accuracy) are also concerned about the mental and time-consuming burden that his additional input would require [1] (i.e., integration into daily life; see Section 4.1-4.3). Such conflicts illustrate the trade-offs involved in designing human-centered WSMT. The articles did not extensively discuss those trade-offs, likely because page limits require authors to be concise. However, understanding and documenting these trade-offs is crucial for advancing the design of human-centered technologies, as it can lead to more balanced solutions that better accommodate individuals' needs and preferences [22]. Future research should delve deeper into these trade-offs, potentially offering guidelines for designers to navigate conflicting facilitators in the development of WSMT.

Finally, facilitators were frequently linked to individuals' *personal preferences*. For instance, some individuals find stress notifications useful [45, 63], whereas others find these annoying and confronting [36, 46, 86] (see Section 4.1). Moreover, some individuals prefer to share their stress measurements with close others so that those others can support them [13, 86], whereas others are uncomfortable with this [13, 86] (see Section 4.1 and 4.4). In line with the growing trend towards personalized eHealth technology [75], these differences in individuals' preferences imply that the design of WSMT could be enhanced by incorporating personalization features. For instance, participants in the study by Elvitigala et al. [18] valued the ability to customize the stress level threshold for stress interventions, allowing them to control how quickly the technology responded to their stress. Future research should further build upon the pointers for opportunities for WSMT personalization that we presented (see adaptiveness and controllability in Section 4.2).

5.3 Future Directions for Designing Wearable Stress Management Technology

To navigate the complexity of designing WSMT, our list of design considerations (see Table 9), while still requiring greater specificity, can be a starting point to inform human-centered design. In line with those, we discuss two main design challenges for WSMT (Section 5.3.1), the need for actionable and balanced recommendations (Section 5.3.2), and we propose a value-sensitive approach to researching and developing WSMT (Section 5.3.3).

5.3.1 Two Main Design Challenges: Understandable Stress Feedback and Acceptable Stress Notifications. While synthesizing the design considerations, we identified two main challenges of designing WSMT: (1) designing understandable stress feedback and (2) designing acceptable stress notifications. These originated from design considerations that require a deeper understanding than our corpus provides before they can be translated into actionable design recommendations (see Table 9).

Designing Understandable Stress Feedback: An important facilitator identified in our analysis was the informativeness of stress response feedback. For instance, smartwatch users disengaged with the stress tracking features of their devices because they did not understand the presented stress scores [17], suggesting the need for clearer guidance in understanding this feedback. Mohr et al. [54] recommend enhancing feedback transparency in personal sensing tools to help individuals understand and take ownership of their data, thereby fostering trust in the technology. Similarly, Coşkun and Karahanoğlu [15] recommend that designers help self-trackers make sense of their data by explaining the meaning behind the numbers and terminology. This guidance could contribute to the clarity and informativeness of WSMT. However, HCI researchers face challenges in mastering the scientific evidence behind stress measuring and management. Once again, bridging various disciplines is essential to designing WSMT that meets user needs and expertise in stress.

An unanswered question remains about the extent to which stress feedback, including visualizations, should be open to user interpretation. Some articles in our corpus used abstract representations of physiological arousal data, using colors, shapes, and compositions to represent different stress levels [21, 37, 68]. A study involving an affective diary indicated that abstract representations of physiological data can help individuals reflect on their emotions and narrate past and present experiences [72]. Consequently, Ståhl et al. [72] recommend that interactive systems avoid dictating the interpretation of body sensor data, instead encouraging active user participation in the interpretive process. Notably, abstract representations of stress feedback in related literature, including metaphors such as weather [80], geometric shapes [87], and trees [88], were reported to be successful in engaging participants and increasing their awareness of stress. Enthusiasm for abstract representations suggests that individuals may prefer abstract yet meaningful representations of stress over objective yet incomprehensible stress scores. Future research should seek to validate these conclusions and explore users' preferences regarding the balance between ambiguity and clarity.

Designing Acceptable Stress Notifications: We also identified challenges in designing effective stress notifications, particularly in balancing the helpfulness of technology with seamlessness and privacy. For notifications and interventions to be helpful, they must seamlessly fit in with users' daily lives– meaning they should not be intrusive and should adapt to the situational context [17, 37, 45, 46] (see Section 4.6). A dedicated branch in HCI research focuses on interruptions in interactive systems [see e.g., 32]. To minimize the stress users experience from interfaces, interactive systems should give users control over interruptions and help mitigate feelings of overwhelm [56]. Furthermore, since stress notifications are dynamic, designing acceptable stress notifications requires a deep understanding of the target group's daily lives. However, understanding the target group alone might not suffice, as users' intentions for using WSMT can evolve. Meyer et al. [52] found that users of activity trackers were initially excited about the detailed data available and accepted more intrusive trackers for the richer information they provided. Over time, they became content with more limited instant feedback if it came from a device that was easier to use in daily life [52]. Therefore, future research should consider the evolving intentions of WSMT users, along with their lifestyle characteristics, to design acceptable stress notifications.

5.3.2 Need for Actionable and Balanced Design Recommendations. Most recommendations provided in our corpus (see Section 4.6 and Appendix A.2) read like general interaction design principles, such as usability guidelines. For instance, one of the recommendations, "the interface should be simple" [39], is a general requirement for graphical user interfaces [e.g., 35]. While general design guidelines are useful when designing WSMT (e.g., general design guidelines for usability [60], wearability [25], health trackers [52], peripheral breathing exercises [73], and factors for sustained use of fitness wearables [12]), the design of WSMT can also benefit from more targeted, actionable recommendations specific to stress management. For example, understanding how to balance the simplicity of interfaces, as recommended [35], with the need to provide sufficient information for contextualizing stress response visualizations (see DeCo12 in Table 9) would be valuable.

Some recommendations were specific to stress management but lacked specificity on their implementation, limiting the actionability of our design considerations (see Section 4.6). For instance, articles in our corpus recommended providing transparent and understandable explanations of stress response feedback [39] but did not clarify what constitutes a transparent and easy-to-understand explanation. Once again, this emphasizes the necessity of investigating individuals' stress literacy levels and their information needs to develop actionable recommendations.

Our thematic analysis revealed that most of the prior work studied functionality-related aspects of WSMT, with subjective experiences addressed only in a few articles. This was evident from the prominence of pragmatic facilitators – such as usefulness, functionality/interactivity, and user privacy – centered around pragmatic aspects such as informativeness and ease of use (see Section 4). In contrast, pleasurable experiences such as smoothness and aesthetics were only found in the two less prominent facilitators (i.e., seamlessness and technology's image). Hassenzahl [29] stresses the importance of hedonic attributes (i.e., pleasure-related attributes) in forming a strong bond between users and products. Since the effectiveness of WSMT depends on the integration into users' daily lives, we recommend that these attributes receive more attention. Therefore, future work should provide a balanced picture by also focusing on the hedonic attributes of interacting with WSMT. Consequently, design recommendations that focus on both pragmatic and hedonic attributes can be formulated.

5.3.3 Considering Value-Sensitive Design of Wearable Stress Management Technology. Our results indicated that a usability taxonomy [3] did not fully capture the variety and nature of the facilitators in our corpus. Participants' perspectives extended beyond usability and user experience, focusing instead on how the technology either supported or impeded what they found important, i.e., their underlying values. We observed various values related to different design features. Privacy was a prominent value that emerged as one of our five main facilitators (see Section 4.4) and was mostly observed in user perspectives on data recording, storage, and sharing. Autonomy was another prominent value, relating to design features that empowered users by increasing control over their lives (e.g., helping them recognize stressors) or minimizing the technology's intrusion into their daily lives (e.g., snoozing stress notifications). Trust was a more implicit value, reflected by the observation that agreement with the data (perceived data accuracy) influenced individuals' engagement with the technology [86]. Privacy, autonomy, and trust were all highlighted as relevant values in a recent bioethical analysis of wearables for stress measurement [11]. Additional values such as justice [11, 82] are also deemed relevant, but the study designs reported in our corpus did not elicit these (see Section 2.4). Arguably, addressing justice might be less of an immediate concern for users but ought to be, at least, the responsibility of the developers. Utilizing a Value-Sensitive Design approach [23] could help uncover these values, providing deeper insights into user needs and concerns and informing human-centered design of WSMT. The work of Kerr et al. [39], although focused on a specific domain (i.e., digital stress management interventions in the office), offers a starting point for further value-sensitive design studies in the field of WSMT.

6 Conclusion

This article reviewed HCI literature that studied user perspectives on WSMT and identified five main facilitators and barriers of this technology (usefulness, functionality/interactivity, seamlessness, user privacy, and technology's image). We also synthesized 18 design considerations, though further research is needed to generate detailed and actionable recommendations. Our review highlighted limitations in the methods and methodologies within the corpus, as well as the inherent complexity of designing human-centered WSMT. We found that some facilitators served as prerequisites for other facilitators and that some facilitators conflicted with others. Additionally, we found that facilitators were frequently linked to individuals' personal preferences, needs, and traits. If designed with a human-centered approach, WSMT presents an opportunity to address the growing burden of stress on our society. Therefore, we recommended adopting a value-sensitive approach to prioritize human values in future WSMT design. Overall, we contribute to the HCI literature by illustrating the complexity of developing WSMT and offering a structured foundation of design considerations for moving forward.

Acknowledgments

This work is funded by Stress in Action. The research project 'Stress in Action': www.stress-in-action.nl is financially supported by the Dutch Research Council and the Dutch Ministry of Education, Culture and Science (NWO gravitation grant number 024.005.010). We thank the anonymous reviewers for their valuable feedback and Jos Nicolai for proofreading our manuscript.

References

[1] Daniel A. Adler, Emily Tseng, Khatiya C. Moon, John Q. Young, John M. Kane, Emanuel Moss, David C. Mohr, and Tanzeem Choudhury. 2022. Burnout and the Quantified Workplace: Tensions around Personal Sensing Interventions for Stress in Resident Physicians. *Proceedings of the ACM on Human Computer Interaction* 6, CSCW2, Article 430. https://doi.org/10.1145/3555531

[2] Rabah M. Al abdi, Ahmad E. Alhitary, Enas W. Abdul Hay, and Areen K. Albashir. 2018. Objective detection of chronic stress using physiological parameters. *Medical & Biological Engineering & Computing* 56, 12. https://doi.org/10.1007/s11517-018-1854-8

[3] David Alonso-Ríos, Ana Vázquez-García, Eduardo Mosqueira-Rey, and V. Moret-Bonillo. 2009. Usability: A Critical Analysis and a Taxonomy. *International Journal of Human-Computer Interaction* 26, 1. https://doi.org/10.1080/10447310903025552

[4] Andrew Baum, J.P. Garofalo, and Ann Marie Yali. 1999. Socioeconomic Status and Chronic Stress: Does Stress Account for SES Effects on Health? *Annals of the New York Academy of Sciences* 896, 1. https://doi.org/10.1111/j.1749-6632.1999.tb08111.x

[5] Julie Bienertova-Vasku, Peter Lenart, and Martin Scheringer. 2020. Eustress and Distress: Neither Good Nor Bad, but Rather the Same? *BioEssays* 42, 7, Article 1900238. https://doi.org/10.1002/bies.201900238

[6] George Boateng, and David Kotz. 2016. StressAware: An app for real-time stress monitoring on the amulet wearable platform. In *Proceedings of the 2016 IEEE MIT Undergraduate Research Technology Conference (URTC)*, November 4-6, 2016, 2016, Cambridge, MA, USA. IEEE, https://doi.org/10.1109/URTC.2016.8284068

[7] Nicolas Boyon, and Bernard Mendez. 2022. Majority of adults report experiencing high levels of stress in past year Retrieved April 1, 2024, from https://www.ipsos.com/en-us/news-polls/world-mental-health-day-monitor-2022

[8] Virginia Braun, and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2. https://doi.org/10.1191/1478088706qp063oa

[9] Gaël Brulé, and Robson Morgan. 2018. Working with stress: can we turn distress into eustress? *Journal of Neuropsychology & Stress Management* 3. https://doi.org/10.31872/2018/JNSM-100104

[10] Tavis S Campbell, Andrea Stevenson, Ross Arena, Trina Hauer, Simon L Bacon, Codie R Rouleau, Colleen Cannon, and James A Stone. 2012. An investigation of the benefits of stress management within a cardiac rehabilitation population. *Journal of cardiopulmonary rehabilitation and prevention* 32, 5. https://doi.org/10.1097/HCR.0b013e318265e0eb

[11] Stefano Canali, Beatrice De Marchi, and Andrea Aliverti. 2023. Wearable Technologies and Stress: Toward an Ethically Grounded Approach. *International journal of environmental research and public health* 20, 18, Article 6737. https://doi.org/10.3390/ijerph20186737

[12] Ana Isabel Canhoto, and Sabrina Arp. 2017. Exploring the factors that support adoption and sustained use of health and fitness wearables. *Journal of Marketing Management* 33, 1-2. https://doi.org/10.1080/0267257X.2016.1234505

[13] Riccardo Chianella, Marco Mandolfo, Riccardo Lolatto, and Margherita Pillan. 2021. Designing for Self-awareness: Evidence-Based Explorations of Multimodal Stress-Tracking Wearables. In *Proceedings of the Human-Computer Interaction. Interaction Techniques and Novel Applications*, July 24-29, 2021, Virtual. Springer, 357-371. https://doi.org/10.1007/978-3-030-78465-2_27

[14] Mesut Çiçek. 2015. Wearable technologies and its future applications. *International Journal of Electrical, Electronics and Data Communication* 3, 4.

[15] Aykut Coşkun, and Armağan Karahanoğlu. 2023. Data Sensemaking in Self-Tracking: Towards a New Generation of Self-Tracking Tools. *International Journal of Human–Computer Interaction* 39, 12. https://doi.org/10.1080/10447318.2022.2075637

[16] Firdaus S. Dhabhar. 2018. The Short-Term Stress Response – Mother Nature's Mechanism for Enhancing Protection and Performance Under Conditions of Threat, Challenge, and Opportunity. *Frontiers in neuroendocrinology* 49. https://doi.org/10.1016/j.yfrne.2018.03.004

[17] Xianghua Ding, Shuhan Wei, Xinning Gui, Ning Gu, and Peng Zhang. 2021. Data Engagement Reconsidered: A Study of Automatic Stress Tracking Technology in Use. In *Proceedings of the CHI '21 Conference on Human Factors in Computing Systems*, May 8-13, 2021, Yokohoma, Japan. ACM, 1-13. https://doi.org/10.1145/3411764.3445763

[18] Don Samitha Elvitigala, Philipp M. Scholl, Hussel Suriyaarachchi, Vipula Dissanayake, and Suranga Nanayakkara. 2021. StressShoe: A DIY Toolkit for just-in-time Personalised Stress Interventions for Office Workers Performing Sedentary Tasks. In *Proceedings of the 23rd International Conference on Mobile Human-Computer Interaction (MobileHCI '21)*, September 27-October 1, 2021, Toulouse & Virtual, France. ACM, 14. https://doi.org/10.1145/3447526.3472023

[19] Elissa S. Epel, Alexandra D. Crosswell, Stefanie E. Mayer, Aric A. Prather, George M. Slavich, Eli Puterman, and Wendy Berry Medes. 2018. More than a feeling: A unified view of stress measurement for population science. *Frontiers in Neuroendocrinology* 49. https://doi.org/10.1016/j.yfrne.2018.03.001

[20] Rossella Ferrari. 2015. Writing narrative style literature reviews. *Medical Writing* 24, 4. https://doi.org/10.1179/2047480615Z.000000000329

[21] Pedro Ferreira, Pedro Sanches, Kristina Höök, and Tove Jaensson. 2008. License to chill! How to Empower Users to Cope with Stress. In *Proceedings of the 5th Nordic conference on Human-computer interaction (NordiCHI)*, October 18-22, 2008, Lund, Sweden. ACM, 123-132. https://doi.org/10.1145/1463160.1463174

[22] Gerhard Fischer. 2018. Identifying and exploring design trade-offs in human-centered design. In *Proceedings of the 2018 International Conference on Advanced Visual Interfaces*, May 29-June 1, 2018, Castiglione della Pescaia, Italy. ACM, https://doi.org/10.1145/3206505.3206514

[23] Batya Friedman. 1996. Value-sensitive design. *Interactions* 3, 6. https://doi.org/10.1145/242485.242493

[24] Shruti Gedam, and Sanchita Paul. 2021. A Review on Mental Stress Detection Using Wearable Sensors and Machine Learning Techniques. *IEEE Access* 9. https://doi.org/10.1109/ACCESS.2021.3085502

[25] Francine Gemperle, Chris Kasabach, John Stivoric, Malcolm Bauer, and Richard Martin. 1998. Design for wearability. In *Proceedings of the Second International Symposium on Wearable Computers*, 19-20 October, 1998, Pittsburgh, PA, USA. IEEE, https://doi.org/10.1109/ISWC.1998.729537

[26] A. Godfrey, V. Hetherington, H. Shum, P. Bonato, N. H. Lovell, and S. Stuart. 2018. From A to Z: Wearable technology explained. *Maturitas* 113. https://doi.org/10.1016/j.maturitas.2018.04.012

[27] Maria Luisa González Ramírez, Juan Pablo García Vázquez, Marcela D. Rodríguez, Luis Alfredo Padilla-López, Gilberto Manuel Galindo-Aldana, and Daniel Cuevas-González. 2023. Wearables for Stress Management: A Scoping Review. *Healthcare* 11, 17. https://doi.org/10.3390/healthcare11172369

[28] Irene Göttgens, and Sabine Oertelt-Prigione. 2021. The Application of Human-Centered Design Approaches in Health Research and Innovation: A Narrative Review of Current Practices. *JMIR Mhealth Uhealth* 9, 12, Article e28102. https://doi.org/10.2196/28102

[29] Marc Hassenzahl. 2018. The Thing and I: Understanding the Relationship Between User and Produ. *Human–Computer Interaction Series*. https://doi.org/10.1007/978-3-319-68213-6_19

[30] Katie Hoemann, Zulqarnain Khan, Mallory J. Feldman, Catie Nielson, Madeleine Devlin, Jennifer Dy, Lisa Feldman Barrett, Jolie B. Wormwood, and Karen S. Quigley. 2020. Context-aware experience sampling reveals the scale of variation in affective experience. *Scientific Reports* 10, 1, Article 12459. https://doi.org/10.1038/s41598-020-69180-y

[31] Richard J Holden, and Ben-Tzion Karsh. 2010. The Technology Acceptance Model: Its past and its future in health care. *Journal of Biomedical Informatics* 43, 1. https://doi.org/10.1016/j.jbi.2009.07.002

[32] Shamsi T. Iqbal, and Eric Horvitz. 2007. Disruption and recovery of computing tasks. In *Proceedings of the CHI '07 Conference on Human Factors in Computing Systems*, April 28-May 3, 2007, San Jose, California, USA. ACM, 677-686. https://doi.org/10.1145/1240624.1240730

[33] Talha Iqbal, Adnan Elahi, Pau Redon, Patricia Vazquez, William Wijns, and Atif Shahzad. 2021. A Review of Biophysiological and Biochemical Indicators of Stress for Connected and Preventive Healthcare. *Diagnostics* 11, 3. https://doi.org/10.3390/diagnostics11030556

[34] Jeremy P Jamieson, Matthew K Nock, and Wendy Berry Mendes. 2011. Mind over Matter: Reappraising Arousal Improves Cardiovascular and Cognitive Responses to Stress. *Journal of Experimental Psychology: General* 141, 3. https://doi.org/10.1037/a0025719

[35] Bernard J. Jansen. 1998. The graphical user interface. *ACM SIGCHI Bulletin* 30, 2. https://doi.org/10.1145/279044.279051

[36] S. Jiang, F. Firouzi, K. Chakrabarty, and E. B. Elbogen. 2022. A Resilient and Hierarchical IoT-Based Solution for Stress Monitoring in Everyday Settings. *IEEE Internet of Things Journal* 9, 12. https://doi.org/10.1109/JIOT.2021.3122015

[37] Yanqi Jiang, Xianghua Ding, Xiaojuan Ma, Zhida Sun, and Ning Gu. 2023. IntimaSea: Exploring Shared Stress Display in Close Relationships. In *Proceedings of the Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, April 23-28, 2023, Hamburg, Germany. ACM, 1-19. https://doi.org/10.1145/3544548.3581000

[38] Chelsea Kelling, Daniella Pitaro, and Jussi Rantala. 2016. Good Vibes: The Impact of Haptic Patterns on Stress Levels. In *Proceedings of the 20th International Academic Mindtrek Conference*, October 17-18, 2016, Tampere, Finland. ACM, 130-136. https://doi.org/10.1145/2994310.2994368

[39] Jasmine I. Kerr, Mara Naegelin, Michaela Benk, v. Wangenheim Florian, Erika Meins, Eleanora Viganò, and Andrea Ferrario. 2023. Investigating Employees' Concerns and Wishes Regarding Digital Stress Management Interventions With Value Sensitive Design: Mixed Methods Study. *Journal of Medical Internet Research* 25. https://doi.org/10.2196/44131

[40] M Kivimäki, J Pentti, JE Ferrie, GD Batty, ST Nyberg, M Jokela, M Virtanen, L Alfredsson, N Dragano, E I Fransson, M Goldberg, A Knutsson, M Koskenvuo, A Koskinen, A Kouvonen, R Luukkonen, T Oksanen, R Rugulies, J Siegrist, A Singh-Manoux, S Suominen, T Theorell, A Väänänen, J Vahtera, PJM Westerholm, H Westerlund, M Zins, T Strandberg, A Steptoe, and J Deanfield. 2018. Work stress and risk of death in men and women with and without cardiometabolic disease: a multicohort study. *The lancet. Diabetes & endocrinology* 6, 9. https://doi.org/10.1016/S2213-8587(18)30140-2

[41] Josephin Klamet, Denys J. C. Matthies, and Michael Minge. 2016. WeaRelaxAble: A Wearable System to Enhance Stress Resistance using Various Kinds of Feedback Stimuli. In *Proceedings of the 3rd International Workshop on Sensor-based Activity Recognition and Interaction*, June 23-24, 2016, Rostock, Germany. ACM, 1-6. https://doi.org/10.1145/2948963.2948965

[42] Rafal Kocielnik, Fabrizio Maria Maggi, Martin Ouwerkerk, and Joyce H. D. M. Westerink. 2013. Smart technologies for long-term stress monitoring at work. In *Proceedings of the 26th IEEE International Symposium on Computer-Based Medical Systems*, June 20-22, 2013, Porto, Portugal. IEEE, 53-58. https://doi.org/10.1109/CBMS.2013.6627764

[43] Rafal Kocielnik, and Natalia Sidorova. 2015. Personalized Stress Management: Enabling Stress Monitoring with LifelogExplorer. *KI - Künstliche Intelligenz* 29, 2. https://doi.org/10.1007/s13218-015-0348-1

[44] Richard S. Lazarus, and Susan Folkman. 1984. *Stress, Appraisal, and Coping.* Springer, New York.

[45] Noelle R. Leonard, Bethany Casarjian, Richard R. Fletcher, Cathleen Praia, Dawa Sherpa, Anna Kelemen, Sonali Rajan, Rasheeda Salaam, Charles M. Cleland, and Marya Viorst Gwadz. 2018. Theoretically-Based Emotion Regulation Strategies Using a Mobile App and Wearable Sensor Among Homeless Adolescent Mothers: Acceptability and Feasibility Study. *JMIR Pediatrics and Parenting* 1, 1. https://doi.org/10.2196/pediatrics.9037

[46] Xueliang Li, Marco C. Rozendaal, Kaspar Jansen, Catholijn Jonker, and Eric Vermetten. 2020. Things that help out: designing smart wearables as partners in stress management. *Ai & Society* 36, 1. https://doi.org/10.1007/s00146-020-01003-0

[47] Diana MacLean, Asta Roseway, and Mary Czerwinski. 2013. MoodWings: A Wearable Biofeedback Device for RealTime Stress Intervention. In *Proceedings of the 6th International Conference on PErvasive Technologies Related to Assistive Environments*, May 29-31, 2013, Rhodes, Greece. ACM, 1-8. https://doi.org/10.1145/2504335.2504406

[48] Julia B. Manning, Ann Blandford, Julian Edbrooke-Childs, and Paul Marshall. 2020. How contextual constraints shape midcareer high school teachers' stress management and use of digital support tools: Qualitative study. *JMIR Mental Health* 7, 4, Article e15416. https://doi.org/10.2196/15416

[49] Marie-France Marin, Catherine Lord, Julie Andrews, Robert-Paul Juster, Shireeen Sindi, Geneviève Arsenault-Lapierre, Alexandra J Fiocco, and Sonia Lupien. 2011. Chronic stress, cognitive functioning and mental health. *Neurobiology of learning and memory* 96, 4. https://doi.org/10.1016/j.nlm.2011.02.016

[50] Bruce S. McEwen. 1998. Protective and Damaging Effects of Stress Mediators. *New England Journal of Medicine* 338, 3. https://doi.org/10.1056/NEJM199801153380307

[51] Marijke Melles, Armagan Albayrak, and Richard Goossens. 2021. Innovating health care: key characteristics of human-centered design. *International Journal for Quality in Health Care* 33. https://doi.org/10.1093/intqhc/mzaa127

[52] Jochen Meyer, Jutta Fortmann, Merlin Wasmann, and Wilko Heuten. 2015. Making Lifelogging Usable: Design Guidelines for Activity Trackers. *MultiMedia Modeling.* https://doi.org/10.1007/978-3-319-14442-9_39

[53] Abigail Millings, Joanna Morris, Angela Rowe, Sally Easton, John K. Martin, Dennis Majoe, and Christine Mohr. 2015. Can the effectiveness of an online stress management program be augmented by wearable sensor technology? *Internet Interventions* 2, 3. https://doi.org/10.1016/j.invent.2015.04.005

[54] David C. Mohr, Mi Zhang, and Stephen M. Schueller. 2017. Personal Sensing: Understanding Mental Health Using Ubiquitous Sensors and Machine Learning. *Annual review of clinical psychology* 13. https://doi.org/10.1146/annurev-clinpsy-032816-044949

[55] Analúcia Morales, Maria Barbosa, Laura Morás, Silvio César Cazella, Lívia F Sgobbi, Iwens Sene, and Gonçalo Marques. 2022. Occupational Stress Monitoring Using Biomarkers and Smartwatches: A Systematic Review. *Sensors* 22, 17. https://doi.org/10.3390/s22176633

[56] Neema Moraveji, and Charlton Soesanto. 2012. Towards stress-less user interfaces: 10 design heuristics based on the psychophysiology of stress. In *Proceedings of the CHI '12 Conference on Human Factors in Computing Systems*, May 5-10, 2012, Austin, Texas, USA. ACM, 1643 - 1648. https://doi.org/10.1145/2212776.2223686

[57] John T. Morris, and Tracey Wallace. 2018. *BreatheWell Wear: Development and Testing of a Stress Management App for TBI and PTSD on Android Wear Smartwatches* Computers Helping People with Special Needs. https://doi.org/10.1007/978-3-319-94274-2_69

[58] Lars Müller, Verónica Rivera-Pelayo, Christine Kunzmann, and Andreas Schmidt. 2011. From Stress Awareness to Coping Strategies of Medical Staff: Supporting reflection on physiological data. In *Proceedings of the International Workshop on Human Behavior Understanding*, November 16, 2011, Amsterdam, The Netherlands. Springer, https://doi.org/10.1007/978-3-642-25446-8_11

[59] Elizabeth C Nelson, Anneke M Sools, Miriam M R Vollenbroek-Hutten, Tilbert Verhagen, and Matthijs Noordzij. 2020. Embodiment of Wearable Technology: Qualitative Longitudinal Study. *JMIR Mhealth Uhealth* 8, 11, Article e16973. https://doi.org/10.2196/16973

[60] Jakob Nielsen. 1994. Enhancing the explanatory power of usability heuristics. In *Proceedings of the CHI '94 Conference on Human Factors in Computing Systems*, April 24-28, 1994, Boston, Massachusetts, USA. ACM, 152-158. https://doi.org/10.1145/191666.191729

[61] Pat Ogden, and Janina Fisher. 2015. *Sensorimotor psychotherapy: Interventions for trauma and attachment.* W. W. Norton & Company, New York.

[62] Lephuong Ong, Wolfgang Linden, and Sandra Young. 2004. Stress management: What is it? *Journal of Psychosomatic Research* 56, 1. https://doi.org/10.1016/S0022-3999(03)00128-4

[63] Rosalind W. Picard, and Karen K. Liu. 2007. Relative subjective count and assessment of interruptive technologies applied to mobile monitoring of stress. *International Journal of Human-Computer Studies* 65, 4. https://doi.org/10.1016/j.ijhcs.2006.11.019

[64] Julie Ray. 2022. World Unhappier, More Stressed Out Than Ever Retrieved April 1, 2024, from https://news.gallup.com/poll/394025/world-unhappier-stressed-ever.aspx#:$\sim$:text$=$In%202021%2C%20four%20in%2010,of%20physical%20pain%20(31%25).

[65] Laura Riolli, and Victor Savicki. 2003. Optimism and Coping as Moderators of the Relationship between Chronic Stress and Burnout. *Psychological Reports* 92, 3 suppl,. https://doi.org/10.2466/pr0.2003.92.3c.1215

[66] Mahnoosh Sadeghi, Kunal Khanade, Farzan Sasangohar, and Steven C. Sutherland. 2018. Design of a Wearable Stress Monitoring Tool for Intensive Care Unit Nursing: Functional Information Requirements Analysis. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 62, 1. https://doi.org/10.1177/1541931218621308

[67] MR Salleh. 2008. Life Event, Stress and Illness. *Malaysian Journal of Medical Sciences* 15, 4.

[68] Pedro Sanches, Kristina Höök, Elsa Vaara, Claus Weymann, Markus Bylund, Pedro Ferreira, Nathalie Peira, and Marie Sjölinder. 2010. Mind the body!: designing a mobile stress management application encouraging personal reflection. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, August 16-20, 2010, Aarhus, Denmark. ACM, 47-56. https://doi.org/10.1145/1858171.1858182

[69] Hans Selye. 1976. *Stress without Distress* Psychopathology of Human Adaptation, Springer, New York. https://doi.org/10.1007/978-1-4684-2238-2_9

[70] J. Shin, J. Moon, B. Kim, J. Eom, N. Park, and K. Lee 2021. *Attention-based stress detection exploiting non-contact monitoring of movement patterns with IR-UWB radar.* City.

[71] Changwon Son, Sudeep Hegde, Carl Markert, Karim Zahed, and Farzan Sasangohar. 2023. Use of a Mobile Biofeedback App to Provide Health Coaching for Stress Self-management: Pilot Quasi-Experiment. *JMIR Formative Research* 7, Article e41018. https://doi.org/10.2196/41018

[72] Anna Ståhl, Kristina Höök, Martin Svensson, Alex S. Taylor, and Marco Combetto. 2008. Experiencing the Affective Diary. *Personal and Ubiquitous Computing* 13, 5. https://doi.org/10.1007/s00779-008-0202-7

[73] Aaron Tabor, Scott Bateman, Erik Scheme, Book Sadprasid, and M.C. Schraefel. 2021. Understanding the Design and Effectiveness of Peripheral Breathing Guide Use During Information Work. In *Proceedings of the CHI '21 Conference on Human Factors in Computing Systems*, May 8-13, 2021, Yokohama, Japan. ACM, https://doi.org/10.1145/3411764.3445388

[74] Gustavo E. Tafet, and Renato Bernardini. 2003. Psychoneuroendocrinological links between chronic stress and depression. *Progress in Neuro-Psychopharmacology and Biological Psychiatry* 27, 6. https://doi.org/10.1016/S0278-5846(03)00162-3

[75] Iris ten Klooster, Hanneke Kip, Lisette van Gemert-Pijnen, Rik Crutzen, and Saskia Kelders. 2024. A Systematic Review on eHealth Technology Personalization Approaches. *iScience.* https://doi.org/10.1016/j.isci.2024.110771

[76] Satoru Tokuhisa. 2009. Aequorin: Design of a system for reduction of the user's stress in one day. In *Proceedings of the 2009 International Conference on Ultra Modern Telecommunications & Workshops (ICUMT)*, October 12-14, 2009, St Petersburg, Russia. IEEE, https://doi.org/10.1109/ICUMT.2009.5345410

[77] Andrea C. Tricco, Erin Lillie, Wasifa Zarin, Kelly K. O'Brien, Heather Colquhoun, Danielle Levac, David Moher, Micah D.J. Peters, Tanya Horsley, Laura Weeks, Susanne Hempel, Elie A. Akl, Christine Chang, Jessie McGowan, Lesley Stewart, Lisa Hartling, Adrian Aldcroft, Michael G. Wilson, Chantelle Garritty, Simon Lewin, Christina M. Godfrey, Marilyn T. Macdonald, Etienne V. Langlois, Karla Soares-Weiser, Jo Moriarty, Tammy Clifford, Özge Tunçalp, and Sharon E. Straus. 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine* 169, 7. https://doi.org/10.7326/M18-0850

[78] Tiffany C Veinot, Hannah Mitchell, and Jessica S Ancker. 2018. Good intentions are not enough: how informatics interventions can worsen inequality. *Journal of the American Medical Informatics Association* 25, 8. https://doi.org/10.1093/jamia/ocy052

[79] Gideon Vos, Kelly Trinh, Zoltan Sarnyai, and Mostafa Rahimi Azghadi. 2023. Generalizable machine learning for stress monitoring from wearable devices: A systematic literature review. *International journal of medical informatics* 173. https://doi.org/10.1016/j.ijmedinf.2023.105026

[80] Nadine Wagener, Marit Bentvelzen, Bastian Dänekas, PawełW. Woźniak, and Jasmin Niess. 2023. VeatherReflect: Employing Weather as Qualitative Representation of Stress Data in Virtual Reality. In *Proceedings of the DIS '23: Designing Interactive Systems Conference*, July 10-14, 2023, Pittsburgh, Pennsylvania, USA. ACM, 446-458. https://doi.org/10.1145/3563657.3596125

[81] Yingding Wang, Nikolai Fischer, and François Bry. 2019. Pervasive Persuasion for Stress Self-Regulation. In *Proceedings of the 2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, March 11-15, 2019, Kyoto, Japan. IEEE, https://doi.org/10.1109/PERCOMW.2019.8730850

[82] MichałWieczorek, and Leon Walter Sebastian Rossmaier. 2023. Healthiness as a Virtue: The Healthism of mHealth and the Challenges to Public Health. *Public Health Ethics* 16, 3. https://doi.org/10.1093/phe/phad019

[83] Brenda K. Wiederhold, Chelsie Boyd, Camelia Sulea, Andrea Gaggioli, and Giuseppe Riva. 2014. Marketing analysis of a positive technology app for the self-management of psychological stress. *Studies in Health Technology and Informatics* 199. https://doi.org/10.3233/978-1-61499-401-5-83

[84] Brent D. Winslow, Rebecca Kwasinski, Jeffrey Hullfish, Mitchell Ruble, Adam Lynch, Timothy Rogers, Debra Nofziger, William Brim, and Craig Woodworth. 2022. Automated stress detection using mobile application and wearable sensors improves symptoms of mental health disorders in military personnel. *Frontiers in Digital Health* 4, Article 919626. https://doi.org/10.3389/fdgth.2022.919626

[85] Yuanjun Wu, Laiyan Zhou, Xuanwei Zhang, Xue Yang, Gabriele Niedermann, and Jianxin Xue. 2022. Psychological distress and eustress in cancer and cancer treatment: Advances and perspectives. *Science advances* 8, 47. https://doi.org/10.1126/sciadv.abq7982

[86] Mengru Xue, Rong-Hao Liang, Jun Hu, Bin Yu, and Loe Feijs. 2022. Understanding How Group Workers Reflect on Organizational Stress with a Shared, Anonymous Heart Rate Variability Data Visualization. In *Proceedings of the CHI '22 Conference on Human Factors in Computing Systems* April 29-May 5, 2022, New Orleans, LA, USA. ACM, 1-7. https://doi.org/10.1145/3491101.3503576

[87] Mengru Xue, Rong-Hao Liang, Bin Yu, Mathias Funk, Jun Hu, and Loe Feijs. 2019. AffectiveWall: Designing Collective Stress-Related Physiological Data Visualization for Reflection. *IEEE Access* 7. https://doi.org/10.1109/ACCESS.2019.2940866

[88] Bin Yu, Mathias Funk, Jun Hu, and Loe Feijs. 2017. StressTree: a metaphorical visualization for biofeedbackassisted stress management. In *Proceedings of the DIS '17: Conference on Designing Interactive Systems*, June 10-14, 2017, Edinburgh, UK. ACM, 333-337. https://doi.org/10.1145/3064663.3064729

[89] Michael G. Ziegler. 2012. *Psychological Stress and the Autonomic Nervous System* (Third edition. ed.). Primer on the Autonomic Nervous System, Academic Press. https://doi.org/10.1016/B978-0-12-386525-0.00061-5

APPENDICES

A.1 Characteristics of Our Corpus

Table 10: Detailed study characteristics.

Ref	Author and Year	Study Goal	Target Group	Method	N	Period of Using the Technology	User Involv.[a]	Design Rec.[b]
[1]	Adler et al., 2022	S1: Elicit requirements; S2: Evaluate lo-fi prototype	Resident physicians	S1:Interview; S2: Interview	S1: 11; S2: 5	Not applicable	Yes	No
[6]	Boateng & Kotz, 2016	Evaluate mid-fi or hi-fi prototype	General audience	Questionnaire	10	1 day (8-12 hours)	No	No
[13]	Chianella et al., 2021	Evaluate mid-fi or hi-fi prototype	General audience	Interview, eye-tracking, questionnaire	16	1 session (40 min)	No	Yes
[17]	Ding et al., 2021	Investigate long-time users' attitudes	General audience	Interview	17	0.5-1 year	Not applicable	Yes
[18]	Elvitigala et al., 2021[c]	S1: Elicit requirements; S2: Evaluate mid-fi or hi-fi prototype	Office workers	S1: Focus group; S2: Interview, questionnaire	S1:10; **S2:10**	4 weeks	Yes	Yes
[21]	Ferreira et al., 2008	Evaluate mid-fi or hi-fi prototype	General audience	Interview	10	Not available (entire session took 2 hours in total)	No	No
[37]	Jiang et al., 2023	S1: Elicit requirements; S2+S3: Evaluate mid-fi or hi-fi prototype	Close friends or family	S1: Design selection session; S2: Interview; S3: Interview	S1: 4; S2: 9; S3: 10	S1: Not applicable; S2: 2 weeks; S3: 4 weeks	Yes	Yes
[38]	Kelling, et al., 2016	Evaluate mid-fi or hi-fi prototype	General audience	Interview, think-aloud task, questionnaire	8	1 session	No	Yes
[39]	Kerr et al., 2023	Evaluate lo-fi prototype	Office workers	Questionnaire	241	Not applicable	Yes	Yes
[41]	Klamet et al., 2016	S1+S2: Elicit requirements	General audience	S1+S2: Questionnaire	S1: 15; S2: 26	S1: 1 session (90 min); S2: 1 session (45 min)	Yes	No
[42]	Kocielnik et al., 2013	Evaluate mid-fi or hi-fi prototype	(Office) workers	Interview	10	4 weeks	No	No
[43]	Kocielnik & Sidorova, 2015	Evaluate mid-fi or hi-fi prototype	General audience	Interview, questionnaire	21	20 days	No	No
[45]	Leonard et al., 2018[d]	Evaluate mid-fi or hi-fi prototype	Homeless adolescent mothers	Interview, questionnaire	**49**	Not available	No	Yes

[46]	Li et al., 2020	Elicit requirements	Veterans with mental health problems	Co-design, video diary, interview	3	Not applicable	Yes	Yes
[47]	MacLean et al., 2013	Evaluate mid-fi or hi-fi prototype	General audience	Questionnaire	11	1 session	No	Yes
[48]	Manning et al., 2020	Investigate long-time users' attitudes, Elicit requirements	Midcareer high school teachers	Interview	14	Not available	Not applicable	No
[53]	Millings et al., 2015	Evaluate mid-fi or hi-fi prototype	General audience	Interview	98	4 weeks	No	No
[57]	Morris et al., 2018	S1+2: Elicit requirements; S3: Evaluate mid-fi or hi-fi prototype	Veterans with mental health problems	S1: Focus group; S2: Ranking; S3: Interview	S1: 5; S2: 4; S3: 20	S1+S2: Not applicable; S3: 2-4 weeks	Yes	No
[58]	Müller et al., 2011	Elicit requirements	Medical staff	Interview, observation	8	2-4 days	Yes	Yes
[63]	Picard & Liu, 2007	Evaluate mid-fi or hi-fi prototype	General audience	Questionnaire	10	8 days	No	Yes
[66]	Sadeghi et al., 2018	Evaluate lo-fi prototype	Nurses	Focus group, questionnaire	14	1 session	Yes	No
[68]	Sanches et al., 2010	Evaluate mid-fi or hi-fi prototype	General audience	Not available	9	6 hours	Yes	Yes
[71]	Son et al., 2023	Evaluate mid-fi or hi-fi prototype	Student veterans	Interview	24	14 weeks	No	No
[76]	Tokuhisa, 2009	Evaluate lo-fi prototype	General audience	Questionnaire	14	1 session	No	No
[81]	Wang et al., 2019	Evaluate mid-fi or hi-fi prototype	General audience	Questionnaire	86	15 days	No	No
[83]	Wiederhold et al., 2014	Evaluate mid-fi or hi-fi prototype	General audience	Questionnaire	65	Not available	No	No
[84]	Winslow et al., 2022	Evaluate mid-fi or hi-fi prototype	Veterans with mental health problems	Questionnaire	30	2-3 months	No	No
[86]	Xue et al., 2022	Evaluate mid-fi or hi-fi prototype	Office workers	Interview	24	5 days	No	Yes

S1 = study 1, S2 = study 2, S3 = study 3

[a] User involv. = was user involvement in the design phase reported?

[b] Design Rec. = were design recommendations provided in the article?

[c] One participant participated in both studies

[d] Only ten participants were interviewed

Table 11: Detailed technology characteristics.

Ref	Author and Year	Device(s) Used	Function of Wearable Device	Physiological Stress Measures	Behavioral Stress Measures	Self-Reported Stress Measures[d]
[1]	Adler et al., 2022	Dashboard, sensors (undefined)	Measurement	None	Sleep, activity, and productivity	Levels of burnout (scale undefined); Self-reported context or comments on own well-being (free text)
[6]	Boateng & Kotz, 2016	Smartwatch, chest band	Smartwatch: measurement + intervention; Chest band: measurement	Heart rate + HRV	None	EMA ("Rate your stress level currently?" "Low" "Medium" "High")
[13]	Chianella et al., 2021	Smartwatch, smartphone	Measurement + intervention	HRV	None	Perceived Stress Scale (PSS) and Subjective Stress-related Symptoms Scale (4S-Q)
[17]	Ding et al., 2021	Smartwatch, smartphone	Measurement + intervention	What is measured by Huawei, Honor, and Garmin smartwatches (mostly HRV-based)	What is measured by Huawei, Honor, and Garmin smartwatches	What is measured by Huawei, Honor, and Garmin smartwatches
[18]	Elvitigala et al., 2021	Shoe-mounted inertial measurement unit, smartphone	Measurement	None	Foot motion + foot posture	None
[21]	Ferreira et al., 2008	Chest band, wrist sensor, smartphone	Measurement	Heart rate	None (but movement was integrated in the visualizations)	None
[37]	Jiang et al., 2023[a]	Smartwatch, smartphone	**Measurement**	HRV	None	None
[38]	Kelling, et al., 2016	Chest band, smart sleeve, smartwatch	Chest band: measurement; Smart sleeve: intervention	Change in heart rate	None	None
[39]	Kerr et al., 2023	Wearables (undefined), computer/ tablet/ smartphone	Measurement	Unspecified (only examples): cardiac activity, physical activity	Unspecified (only examples): body posture, keyboard use, computer mouse use, eye-tracking	Unspecified - "Subjective assessment of stress level"
[41]	Klamet et al., 2016	Pulse oximeter, galvanic skin response sensor, Arduino wristband, Peltier element, vibration motors, headphones	Pulse oximeter and galvanic skin response sensor: measurement; Other devices: intervention	HRV + EDA (only S2 involved stress detection)	None	None
[42]	Kocielnik et al., 2013	Wristband, (pc)	Measurement	EDA	None	Self Assessment Manikin questionnaire (valence, arousal, energy, and dominance)
[43]	Kocielnik & Sidorova, 2015	Wristband, (pc)	Measurement	EDA	None	None

[45]	Leonard et al., 2018	Smartphone, wristband	Measurement	EDA	None	Slider for self-reporting emotional state (”how are you feeling”, scale of 0 (“Bad”) to 100 (“Good”), with neutral (50: “OK”); prompted when user’s EDA reached an individually determined threshold)
[46]	Li et al., 2020	Smart wearables (undefined)	Measurement + intervention	Unspecified (only hypothetical devices)	Unspecified (only hypothetical devices)	Unspecified (only hypothetical devices)
[47]	MacLean et al., 2013	Wearable sensors, wristband with mechanical butterfly	Wearable sensors: measurements; Wristband: intervention	EDA, ECG	None	None
[48]	Manning et al., 2020	Digital tools for stress management (varied)	Measurement + intervention	What is measured by users’ wearable devices (varied)	What is measured by users’ wearable devices (only Fitbit is known)	What is measured by users’ wearable devices (only Fitbit is known)
[53]	Millings et al., 2015	Wearable sensors, (pc)	Measurement	HRV, alpha power (brain waves)	None	None
[57]	Morris et al., 2018[b]	Smartwatch	**Measurement + intervention**	None (heart rate was shown on smartwatch display but not presented as indicator of stress)	None	Stress level on 7-point scale (prompt text unknown)
[58]	Müller et al., 2011	Chest band	Measurement	Heart rate + HRV	Physical activity (nr of steps, intensity)	None
[63]	Picard & Liu, 2007	Chest band, ankle-worn accelerometer, ankle-worn pedometer, IPAQ, location beacons	Measurement	Heart rate (corrected with accelerometer data)	None (but accelerometer data was used to correct physiological stress response measurements; pedometer data was recorded for research purposes only)	”Stress levels”: ”None”, ”Barely”, ”So-so”, ”High”, and ”Way High” (prompted either randomly or sensor-based, i.e.,: when there was ”a change in a context beacon location or when there was a significant “heart-rate change event” as defined mathematically”
[66]	Sadeghi et al., 2018	Smartwatch	Measurement + intervention	Heart rate	Steps walked during work shift	None
[68]	Sanches et al., 2010	Wearable sensors (worn on the ches, wrist(s), or both), smartphone	Measurement	Heart rate + EDA	None (but accelerometer information was integrated in the visualizations)	None
[71]	Son et al., 2023	Smartphone, smartwatch	Measurement + intervention	Heart rate + heart rate trend (higher or lower; not explicitly presented as stress indicator)	None	None
[76]	Tokuhisa, 2009	Ear pulse sensor + iPod touch, display, LED lights	Measurement	Heart rate	None	None

[81]	Wang et al., 2019[c]	Smartwatch, smartphone	**Measurement + intervention**	RMSSD (approximation of HRV)	None	Stress score on slider, left end of axis says ”Relaxed”, right end says ”Stressed” (prompted after detected stress event based on RMSSD)
[83]	Wiederhold et al., 2014[a]	Wristband, smartphone, tablet	**Measurement**	HRV	None	None
[84]	Winslow et al., 2022[a]	Smartphone, smartwatch	**Measurement**	HRV + EDA	None (but embedded IMU gives context to raw HRV and respiration rate data)	Stress level and trigger (scale undefined; prompted when algorithm identified stress based on HRV and respiration rate)
[86]	Xue et al., 2022	Chest band, shared display, pressure sensor	Measurement	HRV (corrected with motion data)	None (but motion data was used to correct physiological stress response measurements; pressure sensor was used to detect whether participants were sitting, working)	None

a In this article, the wearable device (commercial smartwatch) served only as measurement device. However, this particular smartwatch also provides stress feedback (= measurement + intervention).

b Assuming that stress level was entered on smartwatch, not on smartphone/tablet

c Control condition: measurement

d Only self-reported stress measures that are gathered through the technology

A.2 Design Recommendations from Our Corpus

Table 12: Design recommendations from the corpus.

Sub-Facilitator	Design Recommendation	Source
Usefulness-Helpfulness	As for reflection on previous stress experiences, the design should provide meaningful ways to link the users back to their earlier experiences	[46]
	Consider a section listing external links to manage stress or consult professionals in case their stress levels are too high	[13]
	Future work should take into consideration that users may not know how to act upon information about their own affective state; so providing specific, task-based interventions (e.g., calm down when the butterfly moves) may ameliorate this effect	[47]
	One design implication is that effortful communication could be leveraged for expressing care. [..]. We can design mechanisms that require meaningful effort to support caring-through-data, such as waiting for users to discover others' updates and providing the channel and resources to craft their own elaborate messages	[37]
	Prioritize functional aspects over graphical add-ons, such as animations and visual effects	[13]
Usefulness-Informativeness	[..] important experiential qualities needed in the design: an interactive history of prior bodily states [..]	[68]
	[..] making it more possible for users to learn more knowledge about stress [. . .]	[17]
	In addition to a dashboard, a summary about daily/weekly/monthly stress profiles would be highly beneficial to understand key stress points	[18]
	Include a set of definitions of what stress is and how physiological and perceived stress levels can vary	[13]
	Include in-app sections showing the temporal evolution of physiological and perceived stress.	[13]
	Let users see the results for both stress types [physiological and psychological, red.] together and have a direct comparison.	[13]
	Prioritize transparency. The more (relevant) information users see, the more reliable and valuable the experience will feel.	[13]
Functionality / Interactivity – Ease of use	[..] mobility of the sleeve and devices should be considered in the future as well to support the everyday functionality of the system	[38]
	Avoid or limit simultaneous interactions with multiple devices.	[13]
	Actively guide users through the measurement, regardless of the type of commitment required by the data collection protocol.	[13]
	The design of the interface should be [. . .] easy [. . .] to use.	[39]
	When this [simultaneous interactions with multiple devices, red.] cannot be limited, we suggest the implementation of different stimuli, such as haptic or aural stimuli. By associating each stimulus to a certain device, users could be better guided throughout the experience.	[13]
Functionality/ Interactivity - Clarity	[..] important experiential qualities needed in the design: [..] fluent transitions between states for all variables measured [..]	[68]
	[..] making it more possible for users to learn more [..] about what stress means in the device, and more about what the mechanism for tracking is, among other things.	[17]
	Both prompts and feedback should come with the option to review the stress level feedback together with an expert if users believe that the stress level predictions are not reflective of their own assessment.	[39]
	Both prompts and feedback should come with transparent yet easy-to-understand explanations of the predictions	[39]
	The design of the interface should be [. . .] intuitive to use.	[39]
	The design of the interface should be [. . .] understandable [...]	[39]
Functionality / Interactivity - (Perceived) Data accuracy	Although the physiological sensing system was perceived as sufficiently reliable to be used as a reflection tool, designers should still strive to provide accurate physiological measurements in the field.	[86]
	Therefore, the ML model predicting stress levels should be designed accordingly to account for this tendency [being "more worried about being labeled as stressed even if they are not (false positives) compared with not being labeled as stressed even if they are (false negatives)", red.]	[39]
Functionality/ Interactivity - Adaptiveness	[..] design mHealth interventions that use more refined algorithmic tailoring over time based on participants' responses and levels of stress [..].	[45]
	Future work should [..] make sure that the system fires properly for subjects having a range of body-mass index.	[63]

	Specifically, the interaction for reporting current stress should fit with the situation [. . .].	[46]
	They [JITAI prompts and feedback, red.] should also adapt to the increasing competence and progress of users to foster their autonomy.	[39]
	To support casual users engaging with the automatically collected data, there needs to be not simply new ways of data presentation or integration, but new interactive designs to help engage users in the right moment. For example, in addition to increasing tracking frequency, we, like many of our participants, think it would be valuable to provide reminder functions at appropriate times, e.g. when there is a big jump or drop in stress level, or when the stress level exceeds a certain threshold, in order to fully support the situated interpretation process.	[17]
Functionality / Interactivity - Controllability	Our findings underscore the need to design mHealth interventions that use more refined algorithmic tailoring over time based on participants' [...] preferences. For instance, for some participants, receiving an alert in a stressful moment was opportune, whereas for others, it was perceived as irritating	[45]
	[..] users should be allowed to customize whether to turn on the alert and under what circumstances need the alert.	[17]
	Although a JITAI may infer optimal opportune times for intervention delivery [..], the amount and time windows of interaction with the intervention should still be controllable.	[39]
	Hence, a future app designed for personalised stress intervention should facilitate setting up custom reminders and feedback about stress levels according to user preference.	[18]
	Moreover, the settings regarding stress level feedback and exercises should be personalized and adjustable as much as possible.	[39]
Seamlessness- Integration into daily life	Finally, a dSMI should be integrable into existing and commonly used devices as much as possible and run on the available operating systems	[39]
Seamlessness- Comfortability in wear	[..] comfort [..] of the sleeve and devices should be considered in the future as well to support the everyday functionality of the system	[38]
Seamlessness- Unobtrusiveness	[..] the reminder should be provided in a peripheral and non-intrusive way, such as a vibration.	[17]
	Another design implication is creating a balance between timely care and non-disturbing experience.	[37]
	Specifically, the interaction for reporting current stress should [. . .] not disturb any current activities.	[46]
User privacy- Data privacy	For data that must be processed and stored externally, data management should be overseen and executed by a certified third party rather than in company servers	[39]
	Here, our results indicate that data should not be shared with third parties, especially with the management, in an identifiable or a nonaggregated manner.	[39]
	In terms of data, the participants' responses suggest that as little data as possible should be collected ("data minimisation")	[39]
	Share how data is handled and make sure that users know about their data privacy	[13]
	The collected data should be stored and processed locally on their devices as much as possible (ie, client-side processing).	[39]
	Therefore, a VSD-informed dSMI should offer the option to deactivate and activate the monitoring and JITAI component and the associated data collection at any time	[39]
	Users should always be granted [. . .] the option of irreversibly and completely deleting their data.	[39]
	Users should always be granted access to their raw data [. . .].	[39]
	With regard to the system settings of a VSD-informed dSMI, a user should always be able to adjust the degree of privacy, which can include what kinds of, how much, and with whom data are shared.	[39]
User privacy- Discretion	Future system designs should carefully consider how to deliver constant, real-time feedback to users discreetly. Tactile interfaces built into personal effects (e.g., jewelry) are a promising possibility if done abstractly	[47]
	If possible, a VSD-informed dSMI should compute employees' stress levels using more unobtrusive data sources.	[39]
	Smart wearables should be discreet regarding the physical settings and social situations.	[46]
Technology's image- Anthropomorphic attributions	[..] important experiential qualities needed in the design: [..] a sense of aliveness in the interface [..]	[68]
	The smart wearables have to be respectful and show concerns for personal values.	[46]
Technology's image- Aesthetics	[..] important experiential qualities needed in the design: [..] an ambiguous and open but still consistent design allowing for users' own interpretation and reflections.	[68]
	The design of the interface should be simple [. . .]	[39]