Stressed by Design? The Problems of Transferring Interaction Design from Workstations to Mobile Interfaces

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ABSTRACT

Modern technology use has been linked to stress, with detrimental effects for users' health. Evidence indicates that stress is caused by the design of interaction between users and systems. Since the introduction of graphical user interfaces, designing the interaction between computing systems and the user has been largely incremental. Moving from the PC to mobile devices has added new interaction modalities and interaction metaphors, but the overall way we interact is still very similar. However, desktop computers were used in specific office situations, whereas mobile devices are in ubiquitous use. A lot of the experienced stress of users is linked to the interaction design that priorities computer initiated interactions over the real world and focuses on providing as much information as possible. Moving into the future and transferring the current interaction design to augmented reality systems is likely to worsen the problem by increasing causes of stress. In our research, we identified the problems for future interactions with augmented reality systems and propose principles that re-think interaction concepts to tackle the causes of stress. We propose a longer-term vision about how daily interactions might be designed to reduce the demand on the user. Based on this we suggest a research agenda to create the framework for stress-free interactions.

CCS CONCEPTS

• **Human-centered computing → Interaction design theory, concepts and paradigms**; *Interaction paradigms*; *HCI theory, concepts and models*; *Mobile computing*.

KEYWORDS

stress, HCI, interaction design

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1 INTRODUCTION

Modern technology enables constant and ubiquitous access to vast amounts of information. In most societies, people incorporated technology to their daily activities, both in the private and the public spheres. A large part of human interactions is mediated by computers, be it interaction with other humans, or with the large and complex structures of information available to us nowadays. We rely on technology for an important part of our activities: a large variety of occupations consist of working with a computer, and mobile devices are intertwined both in social interaction and individual entertainment. We use online maps to orient ourselves and find directions. We consult digital sources of information for multiple purposes on a daily basis, and make life decisions based on that information. The use of computers, and in particular mobile devices, has become a part of modern society and, in some aspects, mandatory.

Using the very same devices for work and leisure activities has resulted in the blurring of the line between work and private life. Making it possible both to work anywhere and to be reached instantly had a profound impact in work-life balance for people worldwide. Activities that used to be exclusive from the place of work, such as submitting a report or communicating with clients and colleagues, stopped being secluded to the office. Nowadays, it is not rare to see people performing work-related activities at a coffee-shop or even at the beach. The adoption of instant messaging and social media further fostered the expectation of 24/7 availability, permeating the place of work with social and personal activities. This merge between the private and the professional resulted in the constant monitoring of communication channels, the highly frequent switching between activities and threads of thought, and the intake of vasts amounts of information of very diverse importance, nature and quality.

As we have witnessed, the adoption of computers, and particularly of mobile technologies, has empowered people in work and private life. But it also exposed them to amounts of information and stimuli that surpass the natural humans capabilities. These overstimulation and informational overload result in a series of problems, that range from the being unable to assess the quality of information due to its volume (e.g. fake news) to somatic anxiety disorders caused by the constant expectation of randomly distributed stimuli (e.g. phantom notifications [6]). In particular, the overstimulation of the senses has been linked to stress as early as in 1969 [24]. Even if this affliction may seem mild when compare with the ones mentioned above, it is its pervasiveness, and the long term deterioration of health it causes, what makes it arguably the most urgent to deal with.

Current practices in interaction design, both on mobile devices and workstations, do not address this issue: they are the very cause of the problem. The way interaction with information is conceived does not scale up, and with an ever growing amount of information and communication channels, the over-exposure to information and stimuli can only get worse.

In addition to the present problem, current research trends hint to consumer grade mixed-reality (MR) systems, such as the ones used in augmented reality applications (AR), becoming available in the short term. Technology developers are betting on making these technologies widespread and are potentially setting the framework for future ubiquitous interaction spaces. If this will be the new norm, namely the technology that eventually replaces mobile devices, then the incorporation of AR will have stark implications for interaction design, both in the fields of human-computer interaction (HCI) and computer-mediated communication (CMC).

In the particular context of information overload and stress, bad design policies for the deployment of AR interaction can have devastating effects in the human psyche. Nowadays, the physical source of information (and therefore, the stress it causes) is limited mostly to mobile devices and stationary screens. Translating the current interaction space to MR devices means enabling systems to display information on every possible surface and about everything we normally perceive. Making additional streams of information omnipresent is likely to be very detrimental for human cognition and health.

This technological shift has the potential of increasing the baseline stress of interaction with machines and fellow humans, but it can also be an opportunity to change the interaction paradigm.

In this paper we formalize this problem in the context of HCI and describe our long-term vision about a radically different approach to interaction. Based on this idea, we propose a set of design principles to minimize the stress inherent to computer-mediated interactions, be it with humans or digital information structures. These recommendations can be applied both to current and future technology, potentially enabling a smooth transition between interaction design paradigms. Finally, we review the existing literature on stress caused by interaction and propose a research agenda that builds upon these previous work, suggesting the first steps in the direction of materializing our vision.

2 THE RISK OF AUGMENTING INFORMATION STRESS

Current HCI research attempts to tackle the consequences of current HCI problems. This is natural, since the problems of technologies that are already deployed are easier to identify and their drawbacks generate more urgent problems. However, solutions to these issues are mostly damage control and mitigation, since the cost and effort of addressing the cause of these problems is too high. The replacement of current interaction paradigms implies replacing current systems, which costs money and time. This highlights the importance of foreseeing problems and preventing them before technologies are deployed.

Audiovisual MR systems will likely replace mobile devices in the coming years. Interaction design was inherited by mobile devices from stationary computers and will likely be inherited by augmented reality systems. Many elements of this interaction design proved to be of great utility for the platforms of the time in which they were created, back then when personal computers started to proliferate. The use of visual elements, such as files and folders, pop-up dialogues, icons and windows, or even more abstract concepts, such as *selecting* and *pasting*, they all went from non-existence to be a transcultural part of common knowledge in just a couple decades. By the time people started to have access to mobile devices, the use of computers was already a global phenomenon, and a great part of humanity had some level of proficiency in basic interaction with computers. The interaction elements were then inherited by mobile devices, mostly because people already knew them, but also implicitly, because the technological transition was incremental.

This is likely the case for the next stage: AR and VR interfaces already rely to a great extent in interaction metaphors and design principles easily traceable to workstations from over 30 years ago. Of course, icons and windows are still useful (and popular) and are unlikely to disappear from workstations. But along with the positive aspects of the current interaction design paradigm, all the negative aspects can also be transferred to the new interaction platform.

The adoption of current interaction metaphors and design in AR systems will likely reproduce the causes of stress already present in mobile devices. Furthermore, AR can potentially worsen the problem: mobile devices have a limited space and capacity to present stimuli and information to a user, while AR systems can do this everywhere. Presenting users with multiple streams of information, mixed with pervasive advertising and ubiquitous notifications is not an appealing image for the future, but also not an unlikely one. The consequences of this outcome for the psyche of users can go from very annoying to completely devastating.

3 A VISION OF FUTURE INTERACTIONS

In contrast with the grim future that perpetuating current interaction design can create, we propose to imagine a different outcome. Assuming that current research in brain-computer interfaces (BCI) will improve steadily, recognizing mental commands given by users or providing feedback (such as neural stimulation aims to do) are feats we expect can be achieved in the mid term. Assuming a similar research progress in machine learning, computer vision and intent recognition, it is possible to envision a completely different interaction space.

In Table 1, we present our vision in form of compared use case scenario, collating in parallel the present and the envisioned interaction design concepts. This example highlights the contrast between the different design philosophies: *searching* versus *knowing*, *being notified* versus *becoming aware*, and *interacting with a system that mediates information exchange* versus *interacting with reality assisted by a system.* Additionally, the envisioned interaction empowers the user to have access to information on command, but otherwise minimizes the stimuli presented to the user by the system.

In our vision, we draw inspiration from Weiser's dream: computers should enrich our perception and empower our actions, enabling better communication and experience, while explicit interaction with computers should be reduced as much as possible. In the context of information and stress, this approach ensures to minimize the cognitive load created by the interaction.

Finally, we propose an additional change in how we describe interactions: instead of thinking of *augmented reality*, we should think in terms of *augmented senses*. This way, the focus of augmentation is not an object, but the user. Interaction design should not enrich things and situations with information, but enrich how we perceive reality through our senses. Even if this shift in paradigms seems to take place at a philosophical level, its implications for interaction design are practical and concrete.

4 STRATEGIES FOR STRESS-LESS INTERACTION DESIGN

The technology needed to support our vision is not ready yet. However, a set of abstract interaction design principles can be formulated independently from the technical implementation. Thus, we propose to formulate design guidelines to minimize the negative effects of perpetuating the problematic design narratives from the past. These guidelines build upon Bray's design recommendations, which are discussed later, in the Related Work section [3].

(1) Upgrade: Prioritize the replacement of available information with better information, over addition of more information.
(2) Steadiness: Minimize shifts of the focus of attention, as well as interruptions.
(3) Conservation: Consider human attention as a limited resource that needs to be conserved.
(4) Control: Empower the user to manage the information flow at will.

We believe that these design principles can reduce information overload and therefore stress, independently from the underlying technology. Additionally, these principles are a step towards making our vision reality, and support the idea of reframing interaction to *augmented senses* instead of augmented reality. In the following sections, we explain each of these principles in more depth.

4.1 Information upgrade

Augmented reality is mostly audiovisual, and per definition implies an increment of the information we perceive. Still, the manner in which this information is presented can affect the cognitive load it takes from the user. Even in the context of augmented reality, replacing information with better (or *richer*) information is possible.

In this context, we recommend the use of subtle methods of augmentation, which are only obvious under purposeful scrutiny, but remain unnoticed otherwise.

This translates to avoiding the use of text, highlights or markers to present extra information. Instead, additional information can be subtly conveyed by modifying optical properties of individual objects, such as hue, brightness or contrast. More abstract information can be transmitted with subtle but persistent sounds.

4.2 Information steadiness

Forcing the user to re-focus attention requires extra effort and is by itself a cognitive task. To minimize the toll this takes from the

Table 1: Use case scenario

Present	Future
I'm sitting in a coffee-shop, looking through the window. I get curious about a tree on the other side of the street. I grab my phone and snap a picture. I zoom in and inspect the shape of the branches and leaves. I perform a reverse image search, to find out what species it is, and after scrolling through dozens of tree pictures, I find one with the associated information I'm looking for: it is a *pinus pinea*. I switch to the Wikipedia app and read that this species is typical from the Mediterranean region.	I'm sitting in a coffee-shop, looking through the window. I get curious about a tree on the other side of the street. I try to recall the name of the species, and I remember it is a *pinus pinea*. I try to recall more about it, and further information starts to emerge from my memory. This tree is typical from the Mediterranean region. I squint my eyes, and I am able to focus in the tiniest details of the leaves, even from the distance I am.
As I put down my phone, it vibrates. I ignore it, assuming is yet another notification. Then it starts to buzz insistently, so I pick it up again and realize that my friend Ed is calling. I swipe on the screen to answer the call and put the phone to my ear. After the usual salutation, Ed asks why didn't I answer his messages. I apologize, I have probably missed them among other notifications. Ed suggests we meet to talk. I tell him to come over and ask him to hold on while I look for the address of the place. I switch apps in my phone to Google Maps and perform various gestures to share my current location. Then I scroll through my contacts until I find Ed and share the location with him. I put the phone against my ear again, and he confirms he got the address. He says he will be here soon. I look again at the screen and perform a gesture to end the call. I am not sure how long will Ed need to get here.	Suddenly, I become aware that my friend Ed wants to tell me something. I decide to communicate with him, and I can hear his voice in my ears. He greets me and suggests to meet, so I formulate in my mind that he should come over. I think of where I am, and he acknowledges this information and says he will be here soon. I become aware that he will be here in roughly 17 minutes.
I look down at my cup of coffee, wondering if it is still warm enough to drink. I try it and it is distastefully cold. I waive my hand at the waiter to over and order a fresh espresso.	I look down at my cup of coffee, wondering if it is still warm enough to drink. I know it is 29 ° Celsius, so I desist. I look at the waiter, and he nods and starts preparing a fresh espresso.

user's cognitive capacity, the presentation of visual information should take place on the augmented object, or its immediate area.

Abstract information should be presented either as non-positional, ambient audio, or if it must be presented visually, it should be in the general direction that the user is looking at.

The use of sudden or dynamic stimuli, such as pop-ups, blinking text or moving symbols, should be minimized, or if possible, completely avoided. Abrupt changes should be softened, although this should not result in excessively slow transitions, since those might cause anxiety.

4.3 Attention conservation

Attention is a limited, scarce resource and interaction designs should attempt to preserve it.

An additional aspect to take into account is AR's multi-modal nature. Even in the cases in which the provided additional feedback is purely visual, this will be overlaid on top of reality, which we constantly perceive through all our senses. Since attention is limited across senses, it follows that it should be considered as pooled resource.

Based on these assumptions, it is possible to reduce information load, and therefore stress, by minimizing simultaneous multi-modal feedback.

When possible, the sense over which information will be conveyed to the user should also be chosen based on the actual load of each sense.

Additionally, systems could detect when the user acknowledges the presented information and cease the stimuli automatically.

4.4 Information flow control

Since the constant exposure of additional information is detrimental to the user, it is important to decide what and when to display. User-centered design should empower the user, since the user is the agent of decision and choice. Thus, information should be presented on demand by the user, or only when it is extremely important that the user becomes aware of it.

Information with low levels of priority should only be presented to the user when the level of attention of the user allows it, without compromising other activities.

In this way, the user decides about what is presented, thus perceived. This principle could also include all of perception, giving the user power of choice over both augmented sources of information and environmental cues.

4.5 Some considerations

The above described principles are recommendations aiming to reduce the informational overload of users during computer-mediated interactions with machines or people. The reduction of informational overload should result in a reduction of the stress experienced by the user during the interaction. The greater the extent to which these principles are implemented, then greater will be the reduction of stress.

Of course, the stress reduction will only affect the portion of stress caused by the interaction. Other sources of stress will likely remain unaffected by our design recommendations. Thus, it is important to remark that these recommendations will not eliminate stress completely, but reduce the additional stress that is originated in the interaction with devices.

5 RELATED WORK

The research on sensory overstimulation predates HCI, with some remarkable examples such as Zuckerman et al.'s work on its physiological aspects [24] or Ludwig's investigations on how it produces altered states of consciousness, similar to psychedelic experiences [9].

The incorporation of computers and digital means of communication into human activities encountered the limitations to human cognitive capabilities already at its early stages. Hiltz and Turoff recognized the problems of CMC in 1985 [5]. The information overload was later studied by Berghel in the context of the Internet [2], and David Shenk went further to describe its negative impact in all facets of life [16].

The term *Information Pollution* was coined by Nielsen in 2003 to describe the impact of interruptions caused by CMC in performance of workers [12]. This concept was extended by Bray, who also proposed three principles to improve information management:(i) *replacing*[1] available information with better information, instead of adding information on top, (ii) avoiding the use of technologies that imply refocusing attention frequently, and (iii) treating human attention as resource that needs to be conserved [3].

Bawden and Robinson reviewed the negative effects of information technologies in health, predicting the problem to become worse even before mobile phones were a mainstream technology [1]. Thomée et al. linked the usage of mobile phones with stress and sleep problems in a study with over 4000 young adults in 2011 [19], and in 2014, Yin et al. coined the term of "Technostress" to model the stress caused by two main factors: techno-overload and techno-insecurity, both consequence of exposure to excessive amounts of information [22]. Ledzińka and Postek revised this work in 2017, recapitulating the psychological foundations and empirical evidence on information overload and overflow, and proposing the term of "infostress" [7]. Schedyt et al. reviewed the topic from a clinical perspective, suggesting the existence of subjective and objective overload [15].

In the more specific context of HCI, researches have attempted more practical approaches to infostress, both in stress detection and stress reduction. The task of detecting stress is not trivial, as Sanches et al. showed with their explorations on the usage of biosensors for interface design, mostly due to difficulty of performing this task with wearable devices[14]. Diverse attempts to detect stress range from inferring from mouse usage data [18] to skin conductance [8].

Most HCI work about stress reduction can be grouped in two main areas: controlled breathing and self-reflection. Systems that encourage stress management with techniques to control breathing have been implemented for workstations [11], mobile applications [21], virtual reality [4, 17] and even to be used while driving a car [13].

Reducing the stress while driving a car was also the focus of work that uses self-reflection as a stress management technique [10]. However, most applications aim to help users identify the

[1]Emphasis of the original author

causes of stress *offline*, and the actual intervention varies from controlling ambient lights [23], to mindful meditation techniques [20].

5.1 Summary

The literature highlights the negative cognitive effects of exposure to excessive information and links them to stress. This phenomenon has been recognized by psychologists and information science researchers, and a corpus of work in HCI proposed different methodologies to detect and reduce stress, mostly by helping the users control their breathing, or encouraging self-reflection and self-awareness. Still, there is so far no clear attempt to address the causes of stress as a design strategy. We see in this problem a clear opportunity to rethink how interactions are designed and propose designs that result in less stress.

6 RESEARCH AGENDA

The problem identified in the literature is the current state-of-the-art interaction design. To eliminate the stress this causes, it is necessary to design a new way of interaction. We envision a future, where interfaces are implicit, and where we have unlimited access to huge information structures. To ensure that future interaction design liberates users from techno-stress, a series of research projects need to take place.

(1) Conduct a systematic literature review of information stress, as defined by Ledzińka [7], with an emphasis in the augmented senses.
(2) Elaborate a design space for stress-less interactions in augmented reality.
(3) Conduct studies to assess the validity of the design space and its effect in stress reduction.
(4) Explore applications that empower the user to control the information flow with intent (since technology is not mature enough for this, we propose a wizard of Oz approach for these evaluations)

7 CONCLUSION

In this paper we have identified techno-stress as a problem inherent to current interaction design. We propose to re-think human-computer interactions in a way that eliminates stress from future interfaces. Our vision was illustrated with a possible scenario. Even if the technology that will materialize our vision is still somewhere down the road, it is possible to start designing towards that ideal by following the four design principles we propose, namely Upgrade, Steadiness, Conservation and Control. We proposed a research agenda to systematic investigate the identified problem and find formal solutions, thus creating guidelines for a stress-free interaction design.

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