Critical human factors in UI design: How calm technology can inform anticipatory interfaces for limited situational awareness.

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ABSTRACT

Contemporary information and wayfinding design often disregard the changing personal circumstances and mental state of the user. This paper explores concepts and methodologies in user interface (UI) and user experience (UX) design to increase comprehension and retention through the inclusion of human centered design principles and a focus on the participants' individual context, mental state and abilities. The paper focuses on human factors and comprehension in fast changing situations imposing a sudden high cognitive load on to the affected. In a highly stressed condition, visual perception and situation awareness may be restricted due to the impact of sensory symptoms (panic, tunnel vision or limited motor skills), thus calling for a linear course of action to enable the user to concentrate at the task at hand.

Keywords

Human-Computer Interaction (HCI), user interface (UI), calm technology, perception, emergency response.

INTRODUCTION

Mark Weiser and John Seely Brown (1997) coined the term "calm technology" in 1996 and predicted the age of ubiquitous computing. Weiser and Brown announced the development of Human-computer Interaction (HCI) in three major waves: First the era of mainframe computing where one terminal was shared by multiple of people. The second wave is known as the era of personal computing – one computer is used by one person. The third wave is the one we are experiencing right now. Multiple computers in various forms are capable of assisting a single person without demanding conscious input.

The awareness of this third era we are currently experiencing builds the premise of "calm technology" which Weiser and Brown (1995) described as "that which informs but doesn't demand our focus or attention." Calm technology offers many possibilities on exploration for HCI and a number of research projects have been focusing on human computer interaction for natural user interfaces (NUI). In its function a NUI relies on a user's intuition as opposed to the learned and recollected interaction of a graphical user interface (GUI). With the rise of ubiquitous computing and the increasing use of smartphone and other touchscreen technology, we have seen an increase in the application of NUIs for navigating our devices. However, there is no clear line separating what can be considered a classic GUI and a more intuitive NUI. Although NUI on smartphone devices offer more directed and immediate physical interaction, they still rely on principles and rules established by GUI. Missing the GUI affordances in visual communication, the NUI of touchscreen enabled devices are compelling the user to explore and experience since the entire screen will be perceived as interactive. How the interaction is translated into visuals and how these are perceived relies on a wide range of factors and design principles. Semiotics, colour, contrast, layout, typography, interaction design and navigation need to be skilfully aligned to ensure an effective user experience (UX). In addition, human factors need to be considered when designing an effective and contextual UI. Although we have metrics to measure almost everything, what does happen when the user is tired, occupied or busy in any other way may change the intended outcome of a task.

Since having arrived in the era of ubiquitous computing, many products seem to be enhanced by an in-built computer device without considering the possibilities. Although smart technology is accumulating all sorts of personal data, it tends to rather react than proposing an adaptive solution. Context aware UIs can utilise the various sensors of our devices to aid the user in a wide range of circumstances, emergencies being one of them.

In 2006 Nilsen & Bjelland (2006) describe a wide range of physical changes the human body experiences in an emergency situation. The release of epinephrine and cortisol affects the human response and led them to suggest the need for guidelines for design in a context of stressful situations.

This paper suggest a development of UIs that can anticipate and adapt to the specific needs of a user with limited situational awareness considering ergonomics, semiotics and cognitive feedback loops.

RELATED WORK

Meng et al (2016) conceived a touch-less interface for an operating theatre. The premise on this project was to come up with an alternative input device to replace the prevalent use of mouse and keyboard. Meng notes that one of the most important rules in an operation theatre is the maintenance of a sterile environment. They prototyped a solution tracking the user's fingers with a wearable RGB-D sensor strapped to the person's forehead. It enabled the user to navigate a pointer on a screen and allowed for basic interactions with simple, unobtrusive gestures. In this system, traditional input devices like mouse and keyboard have become obsolete and converted into a NUI. However, since tasks in operating theatres are quite complex, this system will need to offer more variations of gestures to accommodate focused and specific interactions. The NUI will stop being natural when gestures need to be learned. Meng's project shows a good concept where context, user need and motion sensors can reduce cognitive load (the amount of cognitive tasks that can be processed at any given time).

As example for calm technology, the electric car company Tesla introduced a camera assisted autopilot system in their cars in 2014. A combination of 8 cameras and 12 ultrasonic sensors are gathering data while the car is in motion. Without driver input the car is capable of avoiding obstacles, matching traffic speed and steering autonomously. While this technology is capable of enhancing the driver's ability to pilot the vehicle, it is important to evaluate this system for its safety features due to possible conflicts between complacency of the driver and reliability of the system.

To combat these issues, the autopilot software is equipped with a collision warning and emergency breaking system. The dialogue of camera and radar system in combination with the car's software collects and evaluates traffic conditions not only as they occur, but are also capable of predicting the path of vehicles in front of the car. With this technology the collision warning system is capable of alerting the driver to an imminent accident seconds before it occurs. If the driver fails to react in time, the emergency braking system will engage and slow the car down. Tesla's research into autonomous driving, its collision warning system, emergency braking combined with ABS brakes are all samples of calm technology. It resides in the periphery of the user and engages only when needed, thus enabling the user to drive in conditions that may require coping with a higher cognitive load than without these systems.

Interface design also can benefit from the inclusion of calm technology. In 2016 a team of Microsoft's research centre (Hinckley et al, 2016) introduced pre-touch sensing for mobile devices. Their project is exploring the possibilities of touch on a mobile prototype hardware sensing the hand grip on the edges of the device as well as anticipating the finger as input device before making contact with the screen. The anticipatory sensing of an interaction is demonstrated with a mobile video interface and an internet browser. In this application, a video fills the entire screen without showing any interfering or obscuring UI elements. As soon as the device senses an approaching finger, navigation elements fade in providing quick comprehension of its functionality and inviting interaction. Another demonstration of the hardware's anticipating sensors shows a calm browser. As before, the hardware is capable of sensing the finger before any interaction occurs and the visuals on the screen show a normal mobile web browser. As soon as a finger hovers over the text, hyperlinks and navigation elements are subtly fading in and encouraging interaction. Currently, mobile devices are incapable in emulating the "hover" state of resting over GUI elements people are used to from desktop computers. This development does introduce additional gestures for mobile devices, thus increasing the combinations and possibilities of interaction. It also demonstrates that sensors on mobile devices encourage new approaches in the development of NUIs allowing for different hierarchies of information display and the inclusion of a calm interface capable of anticipating and adapting to the users' needs.

In the time of ubiquitous computing, user expect more enabling functions that are fit for purpose and less demanding. The designers' task today is to focus on the context, where and how the interface engages affective human-computer interactions. The visual design is only a part of a holistic approach that can be supported by the inclusion of an unobtrusive, calm design.

RESEARCH METHODOLOGIES

To be effective, interface design needs to be contextual – although today's era of ubiquitous computing offer a range of audio-visual, kinetic and tactile interactions we still experience interfaces that rely on our former understanding of HCI. Traditional input devices like mouse and keyboard on stationary computer for navigating a GUI are gradually being replaced by NUIs. The designer of a traditional GUI as seen on a website or computer program only needs to consider a limited number of settings in how the work will be experienced and – in most cases – cater for a person behind a screen using mouse and keyboard as sole input aid. Mobile devices and their included sensors allow for an infinite number of possible situations in which the user can utilise the device. UI designers now need not only consider how their work will be perceived on a smaller screen and only with fingers or speech recognition software as input device, but include awareness of the physical location, time and task to solve. Additionally, advanced application design utilise combinations of built in data gathering technologies like gyroscope, accelerometer, compass, global positioning system (GPS), microphone and camera or communicating data via speaker, screen, vibration alerts or bluetooth.

Mobile applications show their full potential when they are designed with consideration to the technical possibilities and the context of its use. A street map mobile application is superior to a static web app since it can utilise the exact location of the mobile phone and show a directed and personal method of wayfinding. Most of these functions are expected by the user and take place in the foreground of the interface, meaning they are in direct view of the user and unambiguous in their function.

In 1995 Buxton describes an approach of HCI with a simple matrix (Fig.1). In human-human interaction, conscious tasks and intentional activities are considered to take place in the foreground (like conversations, phone calls, etc) while the background is a place were actions occur that can be considered "behind" the foreground or in the periphery. An example would be a person being aware of someone in the next office typing and conclude that this person is busy. The same model in a human-computer interaction context shows the traditional GUI as being in the foreground while tasks that appear to take place without a conscious effort of an interacting person are considered to reside in the background. An example is smart house technology where light goes on automatically when someone is entering the room as opposed to the person manually flicking the switch.

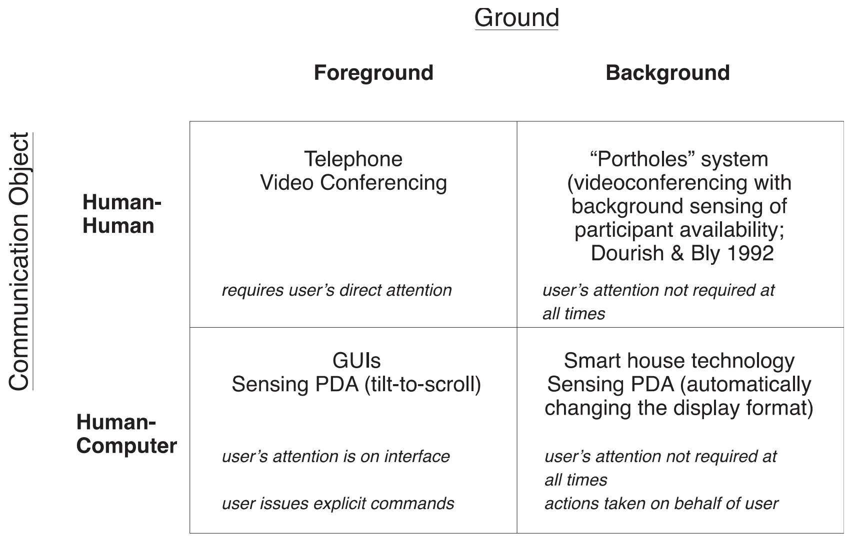

Fig.1

Buxton's model of technology-mediated communication and interaction based on the communication object (human or computer) and the ground (foreground or background), with examples of each class and some distinguishing characteristics.

These technologies are neither new nor uncommon, however one may argue that their more useful features are not only "smart" but "wise", meaning rather than simply reacting to programmed task, they are capable of gathering and utilise data about a situation, adapt the behaviour and even anticipate a user's next move.

In 1991 Weiser explained the underlying concept of calm technology with these words: "The most profound technologies are those that disappear. They weave themselves into the everyday life until they are undistinguishable from it." Weiser (1994) also goes on about his findings and claims that the computer as it is in use today still is the centre of attention rather than to behave like other tools that do not demand focus in order to work as intended. Many designers are still concentrating their efforts in making the interaction the major part of the user experience in which the user has to follow a predetermined set of rules rather than their own intuition. However, since we are getting used to be constantly surrounded by technology, designers seem to catch up and proposing solutions aiding a user with the least interference possible. However, the pendulum can swing both ways and design trends propagating the use of a radically reduced UI (labelled "No-UI") quickly fizzled out when designers became aware that the aesthetics of a polished, image heavy experience interfered with the minimum of a required guidance and affordance.

Weiser (1993) worked closely with John Seely Brown to refine their ideas and form them into guidelines for interaction designers. They considered the era of ubiquitous computing to be the beginning of when calm technology can be explored to its full potential. A prevailing aspect of Weiser & Brown's concept of calm technology is its existence in the periphery of a person. It does not only include the field of vision, but is considered everything in the person's noticeable area of conscious and subconscious awareness, in the same way Buxton explained the foreground - background relationship in human to human and human to computer interaction. The term calm technology is occasionally misunderstood and it needs to be mentioned that the concept of "calm" does not relate to a person experiencing it as a state of mind, but rather the technology being in an engaged but "idle" state. Another relevant characteristic inherent to calm technology is trust. Established (and at the same time unobtrusive) safety features in computational devices designed for transport, sports or healthcare can impose trust on a subconscious level.

Calm technology and design seems to be more prevalent in industrial design practice and often are a less common decision in the planning and design of software applications. However, as previous samples have shown, calm technology in interface design does not only offer a unique and enriching experience, but has the potential to become the prevalent modus operandi in interface design.

In order to utilise the possibilities of calm technology in interface design, the content needs to be separated into the capabilities of the foreground while subsidiary features reside in the background. Both are sympathetic to each other and require to work symbiotically to be effective. Including this, features and foreground – background relationship of calm technology can greatly enhance the experience without overburdening the user. Interaction design making use of calm technology does need to be inclusive and offer the user an initial learning phase to explore what hidden (calm) features can be expected and to what time. Additionally, the user needs to be given a choice to opt-out and use the software without its prosthetic feature. The design needs to work in a dedicated initial state and the prime function of the calm technology is support of the foreground task and only to appear when the need arises.

A conscious design decision in the development is the event or task that precipitate the appearance of the intended function. These are contextual and can range from external as in transmissions sent by official channels over to individual where the device is monitoring the user's behaviour on a repetitive task. In case of multiple connected devices, the combined collected data can immediately be analysed as the sum of the network and translated into useful information aiding in navigation or pinpointing areas of interest.

Stress response in humans:

In 2006 Nielsen and Bjeland describe the human response in a high stress situation and suggest the need for design guidelines. In a stress situation or any emergency situation that triggers a fight or flight response the brain releases epinephrine and cortisol. The former releases energy for your muscles which comes into effect immediately, while cortisol takes about 15 minutes to cut out functions that are not immediately needed for survival. Other physical reactions to stress include: Increased heart rate and blood pressure, diluted pupils, sweating and breathing becomes shorter. Another response noted by Nilsen and Bjelland is cognitive tunnelling – a condition where the stressed person can only focus exclusively on one task occurring with reduced fine motor skills and a narrowed field of vision.

When designing technology for events that impose limited situational awareness in a subject, it is important to avoid stressing an already agitated person and examine the opportunities offered by technology and semiotics to reduce stress. Bertin (1983) propagates clarity to be a key component for ensuring legibility of visual communication and suggest the variety and selectivity of variables to be predictable and founded on a clear message. He devises rules for graphic density as well as retinal variables which can be grouped according to their relative effectiveness (MacEachren, 1995). These variables include orientation, colour, size, texture and shape. Some retinal properties are more effective in disseminating information. Position, for example is the most effective for some type of visual data then other, while grayscale is effective only in a comparative context.

Graphic density also does affect the rate of comprehension speed of a message. The denser the grouping of visual variables, the less the recipient can distinguish between them and read the information. (Bertin, 1983). He also suggest the inclusion of "retinal legibility" – the use of contrast in order to separate between useful primary information and secondary background noise. His concept of predictable information is a direct result of his observations that in many cases background noise has become more visible or even competing with the more important, actual information. Especially in a stress situation, retinal legibility can offer valuable opportunities for fast comprehension when combining variables. It is paramount that a user under stress does not get overburdened with more information but rather enabled to separate between variables and select them by intuition. Bertin states: "When two variables are each associated with a different component, the combination is no longer redundant, it is 'meaningful'".

Colin Ware's (2004) finding on preattentive attributes for information visualisation offers a deeper understanding how these variables can be minimised and utilised to engender an intuitive decision within a split second. Ware suggests the consideration and possible combination of colour, form, movement and spatial positioning of visual elements. Movement in particular lets a navigational element stand out and encourages interaction. The way this movement is perceived by the user can trigger various emotional responses, for example, a very quick transition from one screen view to another suggest a level of urgency, while a subtle and unnoticeably slow transition can evoke the polar opposite.

Concepts and opportunities for UI design in stress situations.

In an emergency situation or any other circumstances that impose a high cognitive load, a user must neither be overwhelmed with new information nor be reminded about their situation. Calm technology enabled interfaces in their natural state can be elaborate, detailed and even customised to personal preference in their appearance and function. After some practice, user learn how to read, navigate and comprehend an interface and its use can become second nature (like using a computer keyboard). In general, a proficient user will have performance expectations that are continously met and without fault. The visual language of the interface is well understood and consistent spatial position of its elements requires low cognitive effort for navigation.

When the user's situation changes from low to high cognitive load – for example in an emergency – the technology may need to change its information density and variables, while maintaining the same visual rhetoric. Design elements may change some of their attributes but need to be consistent in semiotic values and intent. New elements and icons may appear but need to be unambiguous in their visual communication and consistent in appearance of coinciding interface elements. Additionally, the number and density of elements in this 'reactive' interface state need to be lowered and very precise in their conceived function (affordance). Preattentive attributes like colour contrast, typography and to a certain extent movement in scale of important visual elements can influence decisions in a very effective manner, however it is advisable to keep spatial positioning and form consistent with the foreground state. Audio signals like alarms are counterproductive if they produce a continous sound, but can be effective as a subtle reminder that something is about to change.

Examples mentioned in the first chapter could benefit from the inclusion of calm technology in the UI. Meng's interaction design for the operating theater focus on reducing the physical efforts of HCI, but do not include human factors. Visual perception of the interface, its effectiveness in a real patient-surgeon scenario and how the system performs when surgeon or patient encounter an unexpected situation offers an opportunity for further exploration. Interfaces for medical applications have low interactions paired with high information content, meaning the performing surgeon needs to observe multiple information streams simultaneously while having little control of manipulating the presented data. If one of these information streams require more attention (i.e. patient health data) it could increase in size and take up more of the screen real estate reflecting the level of urgency. This transitions in scale need to be subtle and manageable and could also include variable speeds of its transformation for an additional level of information. Albeit having a high information content the inclusion of movement, form and spatial positioning in an animated and fluid UI can promote a quiet and subtle way of communication without stressing an already preoccupied operator.

Previously mentioned Microsoft's calm browser for mobile devices shows a promising start for exploring the technology further by utilising built-in sensors of mobile devices to aid a person in distress. If a device recognises multiple failed attempts to perform an interaction it could increase the touch target size of the area. Data gathered by gyroscope and accelerometer could "stabilise" a selected or entire screen area in a similar fashion a picture stabilising gimbal is capable of levelling a camera, thus enabling a moving person to use an interface simultaneously and uninterrupted.

How the experience unravels is subject to the nature of the emergency and can be separated into two models. The premise of the gradual model (Fig.2) shows a stress situation with slow progress. The user is aware of the situation and has a reasonable timeframe to react. The interface of this model can utilise gradual transitions to reduce its information density depending on the current need.

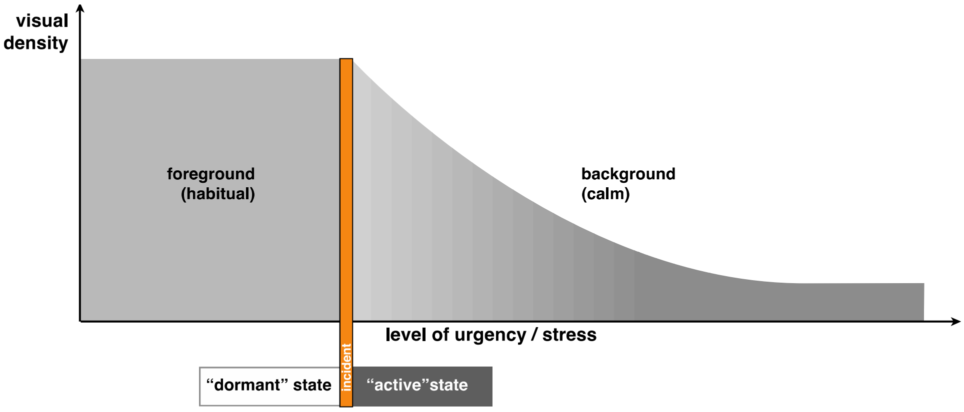

Fig.2

demonstrating the continuum of experience in a calm technology enabled interface relying on a gradual reduction and plain visual language.

The rapid model (Fig, 3) shows an unforeseen stress situation, as in an emergency. The user has no time to prepare and requires a quick and targeted response. The information density immediately needs to be reduced to its essentials in number and detail. There are two more pathways for further progress after the initial shock. Rapid a adapts the information density according to the user’s cognitive capabilities, for example after a successful evacuation. Rapid b keeps the information density to its essentials unless prompted otherwise.

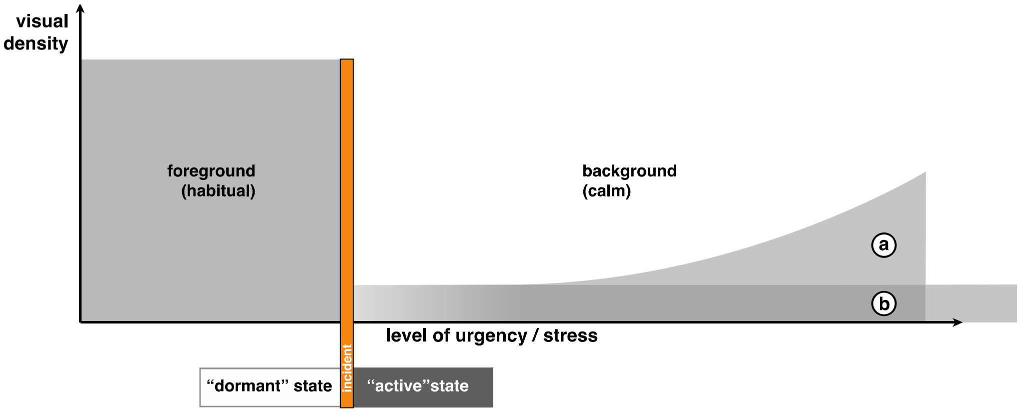

Fig.3

shows the same model relying on a very concise and directed visual language with an opportunity to increase information density if the situation demands it.

Case study – floodscape

Emergency management research has shown that education and awareness campaigns are more successful tools for enabling communities in crises than the building of shelters and central hubs for emergency evacuation. The mobile app Floodscape aims to show a concept of merging adaptive and anticipatory UI while considering the limited cognitive abilities and visual perception of a user in a stress situation. The purpose of this app is building resilience and awareness about tsunami risk in a community, but doubles as a notification and emergency wayfinding system if an actual event should occur. The application is split into two sections: The initial, educational section shows the user what does happen in a large scale tsunami disaster in their community. The UI consists of an elaborate and engaging visual language inviting the user to simulate and experiment with various outcomes of a possible flooding event in their communities. Existing faultlines and plate tectonics of the local area are shown on an interactive 3D map and the user can – choosing from various scenarios – trigger virtual tsunami simulations on their screen. A close up view of the flooded area lets the user explore the outcome in greater detail and offer a starting point for conversations and the planning of possible nearby evacuation routes. The experience design of this educational section is intentionally elaborate, inviting and detailed in order to encourage on-going engagement and discovery. This section of the app advises what group of people the users are most likely want to get in contact with, how they can prepare and where to seek further information. This state of the app is described as “dormant”.

Fig.4

shows the app floodscape with their equivalent functions in both states of their function, ‘dormant’ and ‘active’. Simulations become warnings, risk maps are changing to response maps. The navigation is reduced to most important elements allowing quick access to current location, escape routes, times and notification functions.

The “active” second – calm – section of the app focuses on the timely evacuation and transmission of crucial information needed in an actual event. In case of a verified tsunami warning (and as a response to data dissemination from official channels), the former detailed UI of the first stage makes way for a plain and unambiguous interface catering for a person with limited situational awareness, reduced motor skills and restricted visual perception. Backgrounds have been kept neutral to enhance contrast when needed and colour is only used to shift attention. Background and coloured elements are consistent in their function and denotation throughout the warning stage. Former APIs showing risk maps in the education stage of the app are now converted to response maps and suggested escape routes indicate only the absolute necessary information. In these maps, primary colours are only used for high information content. There are two separate kinds of maps available, a converted risk map focusing on emergency infrastructure and an anticipative, personalised and responsive tracking system displaying the current position and suggesting evacuation routes. This system is especially useful for users not familiar to the location. A countdown displaying the estimate time of arrival of the first wave increases in contrast and size according to the level of urgency. In the development of this section, readability and accessibility of the typography was important. A modular messaging system allows the user to pick a variation from a range of concise sentence modules. These will be compiled into a comprehensible message indicating the level of urgency the user may require help on and can then be sent to predetermined groups like neighbours, family or emergency services.

Overall, the user navigation has been designed so that all interactive elements resemble their function and encourage exploration. The calm stage can be activated anytime and a simulation function lets the user investigate the visuals communication of this stage. Learning and memorising the emergency functions will help in a real tsunami scenario. An audible alarm is only used once for the initial warning and not further repeated to avoid further stressing the affected person.

CONCLUSION

Calm technology is a design philosophy and industrial design practice enhancing the usability of a product without imposing its function on the user experience. Visual perception and other human responses may undergo dramatic changes in a situation of stress and this paper aims to encourage UI designers to include a second, subdued layer of functionality in their products. The goal is to allow information to move in and out of the periphery of the user’s experience and assist in focusing at the task at hand. In the area of UI design, calm technology shows great potential in supporting the user’s needs and ability to focus on what they need, when they need it. Considering and incorporating the concepts of calm technology as a second layer into every day applications can not only aid in the perception of the displayed information but also offer an advantage in timely decision making.

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