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DEPARTMENT: WEARABLE COMPUTING

Whereables? Examining Personal Technology Adoption in Contemporary Control Rooms

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Early work in wearables research has often proposed visions in which wearable computers are introduced to support human operators in critical environments such as control rooms, ship bridges, cockpits, or operating rooms. Wearable assistants could for instance present critical task-relevant information to users regardless of their location, help in avoiding procedural errors, or enhance collaborations between multiple operators. In reality, however, such visions have not galvanized: What happened? And could operators' attitudes and misgivings toward wearables be responsible? The rise of personal wearables in the past years has led to fitness trackers, smartwatches, and other consumer devices being worn by a larger audience, likely also among control room operators. We report in this article on findings from a series of onsite interviews and workshops with professional control room operators to get an insight in their attitude toward wearables, and opinions and current views on the use and adoption of wearable and pervasive technologies in their work environment.

Wearables can serve as personal assistants in many professional settings. They promise to expand the possibilities for users to interact with and perceive their environment, and offer support in making process-critical decisions. This can be done by presenting health and environmental information to the operator that was previously unavailable, such as in the work of Wahl and colleagues.[8] Furthermore, the senses of the user can be extended by the personal assistant, for instance, to increase safety and bring critical information to the foreground. Information can be used by the personal assistant's user to make informed decisions, which can then be further supported by the personal assistants to achieve a positive outcome for the user, such as ensuring safety and adherence to procedures.

User's health feedback: Wearables have been suggested as a way to assess the health status of the user at their workplace. For this, techniques can be borrowed from, for example, the continuous monitoring of patients in medical applications.[5] Wearables that are used to assess athletic performance can also be adapted for monitoring users' vital parameters in a work environment. Systems such as in the work by Zhou et al.[7] can provide new information about the user of the system. Another area where wearables as personal assistants can increase the safety of their users is in the monitoring of fatigue and exhaustion.[12]

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FIGURE 1. Top: The different control room environments we visited included ship bridge training facilities (left), control rooms for fire, and rescue dispatch services (right), and energy distributing centers. The technology in use consists predominantly of desktop computer workstations with keyboard-and-mouse input and a multitude of displays. Wearable devices, if at all present, play a minor and passive role in assisting the human operators. Examples are the use of wireless headphones or personal fall detection sensors. Bottom: Wearables could be integrated in control room environments in a variety of ways, for instance, to assist in responding to emergencies in a timely manner to the right operator, or to avoid overly sedentary behavior of their wearer.

Bringing critical information to the foreground: Research has also led to approaches for using wearables as personal assistants in the area of safety and security, which also offer several possibilities for use in control rooms. A typical example of a personal assistant in the area of safety is the FIREMAN system[11]: Data about the user's breathing are presented to the operator, highlighting previously unobservable information to increase user safety. Another example can be found in the instruction of the particular task at hand, such as in performing resuscitation, where feedback from a wearable can increase the quality of the performed measures.[6]

Ensuring safety and adherence to procedures: In order to increase safety, for example, in environments

where people work nearby dangerous machinery, states, and information about individual systems can be shown to the user by means of a wearable, thus increasing safety and reducing uncertainty in dealing with the machinery.[10] Wearable sensors can also be used to enhance the user's performance through targeted assistance and customized training plans, as well as by assessing a user's performance in a work environment.[9]

THE GAP BETWEEN RESEARCH AND CURRENT PRACTICE

Due to their safety-critical nature, most control rooms tend to adopt technology conservatively. Even though nowadays the "one measurement–one indication" approach[2] is no longer followed and available information technology has changed in many ways (e.g., in terms of computing power, networking, screen resolution), control rooms are still characterized by stationary screen workstations with a handful of screens ("private space") and larger screens/wall installations ("public space"). Therefore, Baber's description of "physically large control rooms with panels containing hard wired meters and other forms of display,"[1] which is now more than 30 years old, is still quite a fitting one of current practice from an human factors and ergonomics perspective.

On the other hand, mobile and wearable devices, let alone more complex approaches like wearable control rooms as suggested by Skourup,[3,4] are hardly widespread—and when they are, they often come in less interactive forms such as wireless headphones or fall sensors.

FEEDBACK FROM CONTROL ROOM PERSONNEL

In 2021, between the COVID-19 waves, in which most control rooms had strict policies in place that prevented any visitors, we were able to visit different types of control rooms throughout Germany and have in-depth discussions with the operators there. We selected as the main control room types an energy control center, a fire and rescue services dispatch center, and a ship bridge training simulator. We talked with the control room experts in a workshop about possible approaches to control rooms as pervasive computing environments and discussed the use of wearables for various conceivable scenarios. The following describes what we have learned from our conversations with the control room experts about feasibility, necessity, and desirability.

Feasible?

Numerous organizational, regulatory and technical hurdles have to be overcome in order to transform research prototypes into market-ready and practical products. This applies all the more to wearables in safety-critical contexts such as control rooms. This will be illustrated by two particular challenges.

The first challenge is that wearables are usually dependent on wireless (network) connections to really show off their strengths and interlink with surrounding systems. However, this is tantamount to a paradigm shift in an otherwise almost hermetically sealed IT infrastructure, which is associated with security concerns. This applies equally to the connection or integration of wearable third-party products that are not supplied by the manufacturers of Supervisory Control and Data Acquisition systems or geographic information systems.

The second challenge is that as the number and types of interaction opportunities for control room operators grow with the introduction of wearables, user interface and interaction design must accommodate this evolution. A mere "more" does not yet bring any of the outlined advantages to bear. Scalable interaction paradigms must address the entire control room setting and not just individual (wearable) components.

The question whether wearables are feasible in control rooms should therefore be answered by a "yes, but": It is not enough to develop and evaluate wearable devices for detached use cases under laboratory conditions – the wearables must be seen as a component in a larger safety-critical system.

Necessary?

Operators in control rooms have an enormous scope of tasks, which they perform conscientiously and responsibly on a daily basis. Nevertheless, there are everyday problems for which human operators have devised various workarounds.

Many processes, such as call distribution to the operators, are rarely targeted by technology. Calls are usually received by all operators, and the next free operator takes the highest priority call. This leads, for example, to the problem that related calls or calls from the same caller are handled by different operators. Another challenge is that the work of an operator is a predominantly sedentary activity at the private workspace. The public displays are either rarely used because there is mainly redundant information, or they are overlooked from the private workspace. Operators only get up for a short period of time during their

shift to make a coffee, go to the bathroom, or go outside for a smoke. Operators being away from their private workspace for a few minutes is an everyday problem in many control rooms. In those minutes, no important information reaches the operator.

A DEEP UNDERSTANDING OF THE OPERATORS' GOALS, MOTIVES, AND NEEDS IS ESSENTIAL, AS IS THEIR CONSTANT INVOLVEMENT IN THE DEVELOPMENT OF WEARABLE SOLUTIONS.

One workaround used in one of the control rooms we visited is to use the building's infrastructure to signal people who go outside to smoke that the person is needed in the control room by briefly raising and lowering the window blinds. Although this has proven helpful, this solution still lacks any feedback to the colleagues in the control rooms as to whether this signal was seen and whether the targeted person is on their way back. Another example is going to the coffee kitchen, which in several control rooms is a physically separated space that is out of view from the control room. Some environments have solved this problem by adding displays in these spaces, to show the most important control room information. However, it remains the operator's task to keep an eye on these displays. In other control room practices, the control room can be seen through a glass wall. Here, the task of the operators is to keep an eye on their workplace from there.

Wearables make it possible for the operators to move freely in the control room without having to keep an eye on their workstation at all times and possibly have to return there quickly to check on important information or when an important call has been received. The control room operators see a lot of potential in this added mobility, especially from a safety, but also from a health, point of view (as many operators do sit on the same chair for most of their shifts).

Might wearables in control rooms be helpful? Yes, because compared to the established tools and workarounds, wearables can contribute to turning the operators' work situation in a more flexible, personalized, and mobile one.

Desired?

Except for headsets with Bluetooth connectivity and established mobile technical solutions (such as smartphones and pagers), no wearables were used in the control rooms visited, nor had any operators interviewed had experience with them in the past. Some operators do wear smartwatches with fitness trackers for personal reasons, showing that they are at least open to this solution in their private lives. But what is their attitude toward it in their working environment? And what is their attitude toward the measured values in relation to the benefits?

Our interviews and an online survey that we administered with more than 150 control room operators from various control room domains showed that operators have a high affinity for technology and are open to new technologies. The operators see high potential in wearables, especially in the flexibility of workflows and mobility at the workplace. Relieving the burden on operators by distributing tasks based on the measurement of cognitive state, appropriate individual presentation of information, identifying tasks and recommendations to support health are definitely desirable for operators.

However, these technological solutions and methods for monitoring of individual data also bring concerns. For example, this data could be sensitive to misuse, such as allowing a company to continuously monitor employee's work performance. A related aspect is the concern about creating a feeling of constant "surveillance," which could stand in the way of acceptance and must be given special consideration when implementing the technology in the control room. Unlike in the aviation domain, for example, where personnel in cockpits are routinely recorded, most control rooms are not completely monitored; they are often limited to recording calls only.

So, should wearables have a place in control rooms? It depends. A deep understanding of the operators' goals, motives, and needs is essential, as is their constant involvement in the development of wearable solutions. Data protection and data sovereignty are especially important when collecting personal data—from operators' vital signs to their whereabouts. Provided this important aspect is taken into account, operators we interviewed were open to the use of wearable tools.

CONCLUSION

So while the question posed at the beginning about the "where?" of wearables in control rooms can still be answered quite clearly ("hardly anywhere"), the answer to the question "Why (not)?" requires a multilayered consideration of feasibility, necessity, and desirability. On the one hand, the value of wearable computing

solutions compared to established standards and processes must be demonstrated. On the other hand, the motivation and "self-image" of the operators must always be taken into account, ensuring a holistic user experience. After all, control room operators will not only wear the wearables, but also bear responsibility for the safety of the control room operation.

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