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Quantifying the effects of external factors on individual performance

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HIGHLIGHTS

- We present a system for monitoring team-performance in real-time.
- We analyze the impact of data collection in the long-term.
- We validate the system with a case-study.
- Emotional valence, conveyed through music, influences team performance.

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ABSTRACT

Monitoring and managing performance in the workplace is nowadays an important aspect, in a time in which methodologies like Agile push individual and team limits further. Current performance monitoring approaches are either intrusive or based on productivity measures and are thus often dreaded by workers. Moreover, these approaches do not take into account the importance and role of the numerous external factors that influence productivity. We present a non-intrusive performance monitoring environment based on behavioral biometrics and real time analytics. It monitors and analyzes 15 features extracted from the workers' interaction with the computer and can provide a measure of performance that is completely transparent. This measure is sensitive to external factors such as mental fatigue, stress or emotional valence. We validate this environment by assessing the effects of musical selection on Human–Computer Interaction. Results show a significant improvement on mouse motion when participants listen to the selected auditory stimuli and a negative effect on typing performance, especially with stimuli with positive tension. This work will enable the development of performance monitoring and management environments, with benefits for both organizations and individuals.

1. Introduction

The Human being is currently under an increasing demand for performance, fruit of a society that is moving faster everyday. Workplaces are particularly "good" examples of this reality. Lack of jobs, decreasing wages, increasing working hours, working in shifts, competitiveness or unrealistic productivity goals result in a constant and increasing pressure on the individual.

Numerous studies highlight the negative effects of this lifestyle. Sparks et al. [1] show positive mean correlations between overall health symptoms, physiological and psychological health symptoms, and hours of work while Dembe et al. [2] analyze the impact of overtime and long work hours on occupational injuries and illnesses, to conclude that these variables depend more on the amount of time worked rather than on the level of risk of the job. In [3], the effects of shift work and extended hours of work are analyzed at different levels, including family and social life, performance, fatigue, productivity and health.

As addressed in detail in [4], there is currently an overwork culture, which is further encouraged by greedy management techniques and job insecurity. While the main objective of management in doing so is to increase production, this does not necessarily happen, nor will it increase productivity.

There is thus the need to improve performance or productivity by other means that do not bring along such negative effects. In this paper we pursue this aim by developing an environment that takes as input individuals' behavioral cues. Indeed, Humans tend to show their personality or their state through their actions, whether in a conscious or unconscious way. The way individuals interact with technological devices is influenced by such factors and can thus be assessed to assess them. Some of these effects, analyzed in

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preliminary studies, show that our performance tends to decrease with the onset of mental fatigue [5] or that the way we touch or handle a smartphone changes with our level of stress [6].

This means that the performance of each individual in a group (and consequently of the group) can be assessed in real time and continuously, instead of being assessed on a regular basis as happens with traditional approaches (e.g. weekly, monthly, yearly). Moreover, workers are more likely to accept this kind of performance monitoring as opposed to traditional measures based on productivity indicators, which are often dreaded and may even result in decreased performance or productivity due to the pressure of monitoring [7]. The privacy of the worker is thus safeguarded.

This approach also translates into a range of other advantages. Namely, it is non-invasive and non-intrusive as it requires no specific interactions by the workers. In that sense, the approach is also transparent. We validate the proposed environment by assessing performance in real time of three groups of people. Moreover, we assess the effect of musical selection on performance.

We do this aiming at the main goal of this line of research, which is not only to monitor performance but also to manage and improve it. The fact that we pursue performance improvement through the use of music may yield additional advantages as described in Section 2.1 (e.g. mood, well-being), as opposed to the culturally established use of punishments (e.g. economic, withdrawal of benefits) or intimidation (e.g. threatening to lose job, preventing career promotion), with negative side effects.

In the overall, this approach is expected to result in better, more efficient and easier to implement performance monitoring initiatives in the workplace, that take into account the worker's well-being and satisfaction.

The remaining of the paper is organized as follows. Section 2 addresses some related work on the field of Human–Computer Interaction and deals with some of the effects of music on the Human being at different levels. Section 3 describes the intelligent environment for real time performance management, including a detailed description of the interaction features considered as well as an analysis of the system's scalability. Section 4 describes in detail the experimental study carried out with the aims to: (1) validate the environment developed and (2) assess the influence of external factors on worker performance. It includes a description of the study design, a thorough characterization of the population (including an emotional and personality characterization) as well as the process followed to validate the auditory stimuli used in the study. The next section details the results of the study in what concerns Human–Computer Interaction. Finally, Section 6 discusses the results achieved and summarizes the conclusions.

2. Related work

In the last years there has been a growing interest in the use of the affective state of computer users, namely to develop applications or hardware that adapt to their users [8]. However, the interest in affective computing goes beyond the sheer acquisition of this information: there is also an interest in how knowledge about affective states can be used to improve the current state of the user. Two main challenges thus exist in this field: how to acquire this kind of information and how to act on the user state. In this paper we look at Behavioral Biometrics for the purpose of information acquisition and at music to influence the affective state.

Behavioral Biometrics defines a field that extracts user's behavioral features from the use of the mouse and the keyboard [9]. Traditional biometrics use human physical or physiological characteristics that are virtually unique for each individual, including fingerprints, iris or face recognition, palm print or veins, among others [10]. These characteristics are used mostly for the purpose of identification. Behavioral Biometrics, on the other hand, rely on behavioral traits of the individual such as typing rhythm, gait, voice, among others. While Behavioral Biometrics can also be used for identification purposes, its features are prone to change according to the inner state of the individual. For example, a stressed individual may show significant differences in speech, reducing the accuracy of identification. Nonetheless, this allows for other interesting applications, namely to assess behavioral changes. Knowing how a individual usually behaves allows to detect significant behavioral changes, which may in turn indicate changes in the inner state of the individual.

In this field, the mouse and keyboard have been used in the last years as the source of valuable inputs for behavioral patterns analysis, known respectively as mouse and keyboard dynamics. These two approaches have been consistently used in the last years for a wide range of different purposes.

Shukla et al. look at the user's typing behavior to identify emotional states [11]. The authors use a total of 8 features: session time, keystroke latency, dwell time, sequence, typing speed, frequency of error, pause rate and capitalization rate. Questionnaires were used to assess the emotional state of the participants. All this data was then used to train classifiers for human emotion recognition from the keyboard typing patterns. In a related approach, the authors of [12] analyze typing behavior against positive/negative emotions. Its main conclusion is that all participants have shown significant differences in typing patterns when under positive and negative emotions, elicited through facial feedback [13]. 15 individuals participated in the study, which only considered the valence of emotion (positive and negative) and two interaction features (keystroke duration and latency). The results support the claim that different emotional valences result in different typing behaviors. Further emotion recognition methods based on keystroke dynamics and mouse movements can be found in [14].

Typing behavior has also been used by [15] to determine the effect of music and induced mental load in a word processing task. The authors measured typing force, typing productivity, and electromyography of the left hand *extensor digitorum* muscle, concluding that overall typing productivity was compromised by music while also observing a reduction of wrong finger touch during typing. Music also resulted in an increased *extensor digitorum* muscle activity for lifting and controlling fingers. Nonetheless, only 8 individuals participated in this study, rendering these results rather limited.

Behavioral Biometrics have also been used for the purpose of user identification. Several research works can be pointed out that Mouse Dynamics for this specific purpose. Both holistic features (single-click statistics, double-click statistics, movement offset and movement elapsed time) and procedural features (speed curve against time and acceleration curve against time) to characterize mouse movement are used in [16]. The authors conducted a study with 37 participants, in which satisfying acceptance rate were obtained with only 11.8 s of interaction. Similarly, [17] use 25 participants and 5 features that model clicking rhythm, which quantify different timings between clicks and during clicks. While the previous work used mostly mouse movement, this one uses mouse clicking alone. They could thus be used in conjunction, in an attempt to develop a more precise approach. Other approaches have been analyzed by [18], who review existing authentication approaches based on mouse dynamics and shed light on some important limitations regarding how the effectiveness of these approaches has been evaluated in the past. The authors also present the results of several experiments conducted by them to illustrate their observations and suggest guidelines for evaluating future authentication approaches based on mouse dynamics.

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