Forecasting Biorhythms for Preventative Stress Interventions

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ABSTRACT

According to the American Psychological Association, 49% of the U.S. population suffers from chronic, daily stress. Chronic stress also has significant long-term behavioral and physical health consequences, including an increased risk of cardiovascular disease, cancer, anxiety and depression. In this position paper, we propose a conceptual framework for thinking through the timing of mobile interventions for stress. One key insight of the work is the need to robustly and accurately forecast future health states to enable preventative interventions. Integrating forecasting into mobile intervention systems raises new questions and challenges in system design choices, evaluating intervention effectiveness, and ethics.

Author Keywords

Ecological Momentary Intervention; Just-in-Time Intervention; Mobile Health

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

General Terms

Human Factors; Design; Measurement.

INTRODUCTION

Advancements in mobile computing and sensing are rapidly changing preventative healthcare. Under the status quo, the average healthy individual visits the doctor rarely, perhaps just once a year [10]. The doctor assesses the patient and then may prescribe medications, recommend changes in behavior (reduce fat consumption, exercise more, etc.), and other forms of intervention. One year later, the patient returns and this process is repeated.

In the emerging new model of health care, the patient is augmented with a smartphone and other sensors that monitor personal health in real-time, as the patient goes about his/her normal daily life [6]. The smartphone and cloud-based services assess the monitored data on the order of minutes (or seconds, if needed), far more frequently than the typical yearly basis. As a result, health interventions can also be prescribed and revised far more frequently. They can be personalized to the instantaneous health status of the patient and delivered precisely when and where needed.

This new model of healthcare is a combination of several concepts. Ecological momentary intervention (EMI) [5] involves delivering an intervention to an individual in his/her natural environment. Adaptive/dynamic intervention [1] is the adaptation of interventions to both the context of the individual and the success of previous interventions. Just-in-time intervention [1] refers to the notion of delivering an intervention exactly when needed (i.e. neither too early nor too late to help the patient). In this paper, we investigate the characteristics of an amalgamation of these concepts and their implications for the design of such systems. All of the above is possible because we can now measures health states, such as stress [3, 7, 9] and physical activity [2, 8] in the natural environment.

We propose a framework for thinking about the timing of such interventions. We introduce three types of interventions, reflectors, mitigators, and preventers and identify design challenges in enabling their use on mobile devices. We examine these design challenges in the context of delivering interventions for chronic stress. Stress is a "silent killer," in that the negative impacts of stress on the body are not instantaneously noticeable. Rather, the effects of stress accumulate over time and lead to significant wear and tear on the cardiovascular system [4]. A well-designed mobile intervention system could reduce the accumulation of negative effects by helping individuals better manage daily stress level.

INTERVENTION TIMING

This section develops a framework for reasoning about the timing of a mobile intervention. The framework is event-based, in that the timing of the intervention is determined with respect to a health event of interest. A health event could be craving a cigarette, eating a slice of chocolate cake, or an episode of high stress. Here, we use an episode of stress as the health event of interest, but the concepts and definitions generalize to other health events.

Assume that stress is a positive continuous signal whose amplitude corresponds to the level/intensity/severity of stress. Thus, waves in the signal (a period of increasing intensity followed by decreasing intensity) are considered stress episodes

(Figure 1). From this, we say that an intervention is effective if it modifies the shape of the original stress episode wave, such that the stress episode has a shorter duration and/or is less intense. The level of effectiveness of the intervention is thus measured as the difference in width and height between the original stress wave (i.e., no intervention) and the intervention-modified stress wave (Figure 1).

Mitigators and Reflectors

Within this framework, we can identify two types of interventions, reflectors and mitigators. **Reflectors** (Figure 2) encourage the user to reflect on the causes of a recent but already past stress episode so that users can better cope with similar episodes in the future. **Mitigators** reduce the intensity or duration of a current stress episode.

Timing is the operational difference between mitigators and reflectors. If the stress episode has already passed, then the only intervention possible is a reflector. If the stress episode has not yet passed, then a mitigator can be used during (or perhaps before) a stress episode occurs to mitigate the episode's effects (Figure 1).
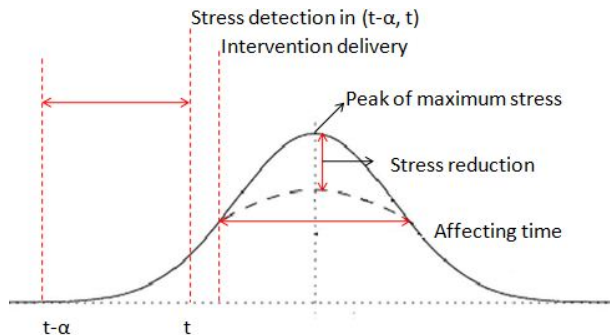

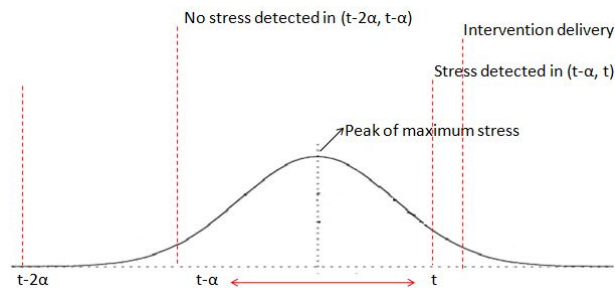**Figure 1. The effect of an ideal mitigator intervention on a stress episode**

Figure 2. A reflector intervention is applied after a stress episode

Preventers

An important sub-case of mitigators are **preventers**. Preventers aim to prevent the occurrence of a stress episode altogether. By definition, preventers must occur before a stress episode begins. Figure 3 demonstrates the application of an ideal preventer to a stress episode. If the preventer is applied, the stress episode is eliminated.

CRITICAL QUESTIONS AND DESIGN ISSUES

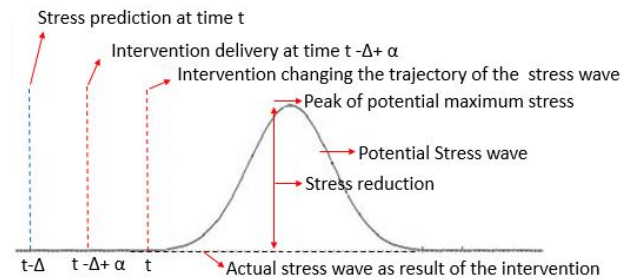### Preventers Require Robust, Validated Forecasting

Figure 3. Stress prevention using stress forecasting

Preventer interventions are not possible without **real-time forecasting** of the stress state of the user. Forecasting enables predicting if a stress episode will occur in the future. If we can forecast a stress episode is coming, we can provide an intervention before the episode occurs altogether.

Forecasting Horizon

How far into the future do we need to forecast to ensure a positive outcome? If we forecast a stress episode will begin in one minute, does that leave enough time for the preventer's effects to take hold ?

Inaccurate Forecasting

It is likely that forecasters will not be perfect. This means users may receive interventions when they don't need them or may not receive interventions when they are needed. What are the consequences of inaccurate forecasts, and by extension, poorly timed interventions?

Measuring Intervention Effectiveness

It is difficult to measure the effectiveness of any intervention (including preventers), as applying a successful intervention ensures we never see the original expected shape of the wave. That said, the effectiveness of mitigators could be assessed by comparison of the characteristics of the stress episode wave before and after the intervention is applied.

For preventers, we propose two options for assessing effectiveness. In the first, the shape of the stress curve is compared to the ideal outcome of the intervention (essentially, a straight line with intensity 0). Alternatively, we can compare the result of the intervention to what might have happened if the intervention never occurred. This approach further emphasizes the need for a robust and validated method to forecast stress.

A Stress-Free Life

If preventers are consistently delivered with ideal timing, it is conceivable that someone might rarely or never feel stress. Is this the a desirable goal for a stress intervention system?

Free Will

If forecasting triggers interventions that change your future behavior it is by definition taking free will away from the user. Is this ethical?

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