Associations between hearing performance and physiological measures - an overview and outlook

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Abstract. The current paper summarises the research investigating associations between physiological data and hearing performance. An overview of state-of-the-art research and literature is given as well as promising directions for associations between physiological data and data regarding hearing loss and hearing performance. The physiological parameters included in this paper are: electrodermal activity, heart rate variability, blood pressure, blood oxygenation and respiratory rate. Furthermore, the environmental and behavioural measurements of physical activity and body mass index, alcohol consumption and smoking have been included. So far, only electrodermal activity and heart rate variability are physiological signals simultaneously associated with hearing loss or hearing performance. Initial findings suggest blood pressure and respiratory rate to be the most promising physiological measures that relate to hearing loss and hearing performance.

Keywords. hearing loss, hearing performance, sensors, wearables, physiological measures

Introduction

One of the fastest growing markets of this decade is that of the wearable healthcare devices (i.e. smartwatches and wristbands) [1]. Given the amount of data that such devices record, they make possible the collection of large heterogeneous datasets that combine data from wearables with observations and monitoring of people with a known health-related condition, e.g. hearing loss (HL). These data can help shape evidence-informed public health policies, which require data provided by and for technological, clinical, legislative and political actors.

The EVOTION project (http://h2020evotion.eu) funded under the Horizon 2020 programme of the European Union uses data collected from hearing aids (HA) and sensors included in a wearable (smartwatch) to assist in the formulation of evidence-

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informed public health decision models in HL related policy making.

To do so, it is crucial to establish a basis for associations between existing sensor technology, as they are included in wearables, and HL and hearing performance (HP). Therefore, for the first part we considered sensors measuring physiological data, namely skin conductance -also known as electrodermal activity (EA)-, heart rate variability (HRV), respiratory rate (RR), oxygen saturation levels (SpO2) and blood pressure (BP). The hearing measures part includes the severity of HL and HP, such as speech understanding or listening effort.

1. State-of-the-Art Analysis

Published research has so far focused on relating HL and two physiological parameters: EA and HRV. Summarising the literature published over the last 5 years (2012-2017), we have grouped the reviewed publications that measure associations with the physiological parameter they have researched, as shown in Table 1.

Table 1. Published research and the physiological parameter correlating with either HL or HP.

Physiological Measurement	Related Studies
Electrodermal Activity	[2], [3]
Heart Rate Variability	[3], [4]
Blood pressure	[4], [5]
Blood Oxygenation	None
Respiratory Rate	[3]
Environmental/Behavioural Relations	**Related Studies**
Smoking	[6],[7],[8],[9]
Physical Activity	[9],[10],[11],[12]
Body Mass Index (BMI)	[8],[9],[11],[12]
Alcohol consumption	[7],[13]

Below we present the results outlined by reviewing the aforementioned studies:

1.1. Electrodermal Activity

EA can be used as a measure of the stress that a person experiences. A change in the impedance of the skin, due to altering transpiration, is measured and used to determine the electrodermal activity. Speech recognition tests have been conducted: listeners were asked to rate the difficulty of understanding speech samples masked in noise in varying signal-to-noise ratios. During these subjective listening effort tests, skin conductance was measured. EA was then associated with increased listening effort (HP). [2,3] The results showed an increased EA for higher effort, displaying a higher stress level in harder listening situations.

1.2. Heart Rate Variability

Like EA, HRV is a measure of the stress that a person experiences. [3 and 7] found HRV to be associated with HP. In subjective listening effort tests (described in *1.1.*), this stress parameter has been measured simultaneously. With increasing difficulty, the HRV was decreasing, signalling higher stress levels. [3] Furthermore, people who experienced a sudden HL showed a lower HRV during night time measurements. [4]

1.3. Blood Pressure

BP is associated with HL. However, the conducted studies [4,5] were carried out through a longitudinal design. They found that higher BP is associated with a higher risk of experiencing a HL later in life [4]. Furthermore, people exposed to noise in the workplace have reportedly higher BP. [5]

1.4. Respiratory Rate and Blood Oxygenation

The literature currently published does not show any associations between other biosignals (RR and SpO2) and HL nor HP. No studies investigate the relationship between SpO2 and HL nor HP. In [3] RR was not associated with HL nor HP.

1.5. Environmental and Behavioural Associations

Environmental parameters, such as BP, have been investigated longitudinally for their association with HL and HP.

The amount of smoking was in [6-8] associated with severity of HL. Physical activity seems to prevent or delay HL. [10,11] Findings also suggest that a higher BMI increase the chance of HL for women [11], whereas men seem less affected. [9] Conversely, [10,12] found that HL can lead to decreased physical activity and less healthy lifestyle in older citizens. In [13] the type of consumed alcoholic beverages was associated with a risk of HL. Women, who reportedly consumed beer had a statistically higher chance of suffering a HL. Whereas, those drinking a moderate amount of wine, had a significantly lower chance.

2. Discussion

The link between HL/HP and environmental and behavioural factors have been studied far more than with physiological measures. The development of wearable technology supports the research conducted in the HL/HP field, as more parameters can be measured with every new smart device. The selected parameters reflect the parasympathetic and sympathetic nervous system and can therefore be directly correlated to HL; as shown in the reviewed studies, the human body reacts to the increased difficulty of understanding things due to HL. Existing, commercially available devices form a solid base on which researchers can build on, along with an increase in the variety of physiological parameters that can be measured over the past years. Research-focused wearables are also being introduced to the market at a steady rate, making data collections from these wearables and their related software more accessible to researchers.

So far, only two parameters have been correlated with HL/HR: HRV and EA. Both have been linked to stress and listening effort. Research has yet to discover the correlations and physiological responses and HP. The first five listed parameters (EA, HRV, RR, SpO2 and BP) can be measured with a good time resolution and associated with HP, as measurements can be carried out simultaneously to listening tests.

The increased stress levels can be transferred into the real world, in stating that people experiencing hearing difficulties as a result of a HL suffer more stress symptoms.

Environmental relations are important to see trends, but they require longitudinal studies to uncover associations with HL.

3. Conclusion

As our results indicate, the field of research investigating associations between hearing and physiological parameters is currently immature. Based on the state-of-the-art research, mainly stress indicators, like RR, EA and BP, should be favoured as parameters to be tested and correlated with hearing measures, e.g. listening effort. A special interest should be given to BP, as this parameter has already been proven to be correlated with HL in longitudinal studies.

A better understanding of associations between hearing and physiological parameters will help policy-makers find right solutions that protect and support those in need. Enabling better continuous access to heterogeneous data sets, thus allowing better and more information bestowed upon researchers, policymakers, and other actors involved in policymaking, is paramount.

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