Individualized closed-loop sensorized virtual reality for behavioral change

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Aims achieved during months 1-9 (May 2018 – January 2019)

In the first 8 months of the project we were able to establish **a proof-of-concept** showing a **high resolution, wireless surface electromyography (sEMG) recordings during VR engagement combined with eye-tracking.** To the best of our knowledge, this is the first demonstration of a system capable of recording internal states during a VR task. Figure 1 shows the 16 channel wireless facial EMG with the VR headset on a participant face.

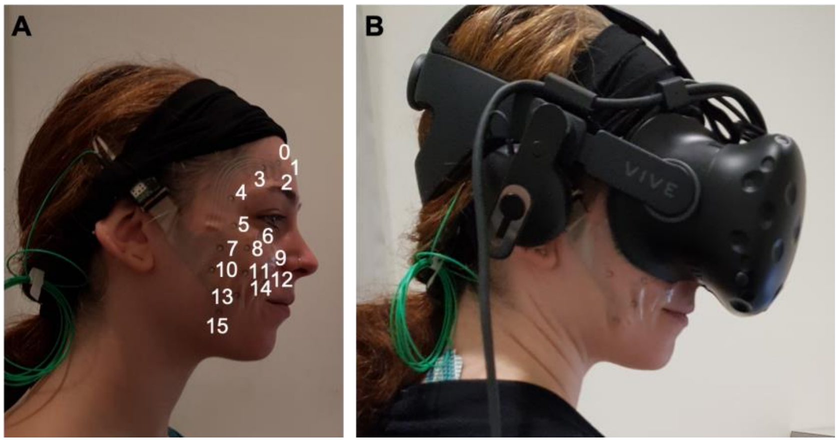

Figure 1: Sensorized VR setup. **A**) sEMG electrode array with 16 channels location and a wireless amplifier. **B**) HTC-Vive VR headset, combined with Tobii's eye-tracker, positioned on top of the sEMG electrodes array.

We show for the first time **the ability to identify different expressions** with the unique sEMG electrodes while wearing the VR headset. Figure 2 shows differential signals for different facial expressions during a calibration phase: closed smile, open smile, disgust and anger.

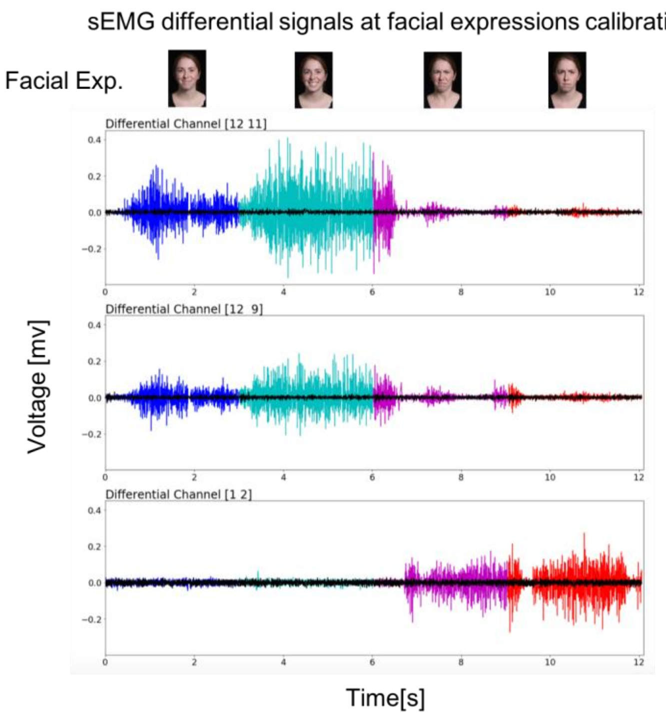

Figure 2: sEMG differential signals during calibration and rest in the VR task. Colors code for different facial expressions. Each panel plots a different combination of channels. For channels location refer to Figure 1.

In the past 8 months we **developed a dynamic VR task** (Figure 3) using the Unity software. The VR task induces positive internal states (For example a cute creature, Figure 3A, 3B top) and allows to compare these responses to the response to neutral (geometric, Figures 3A, 3B bottom) figures in a controlled fashion. While participants explore a house using head movements within the VR task, animals and control objects appear in pre-defined random places. as can be seen in Figure 3.

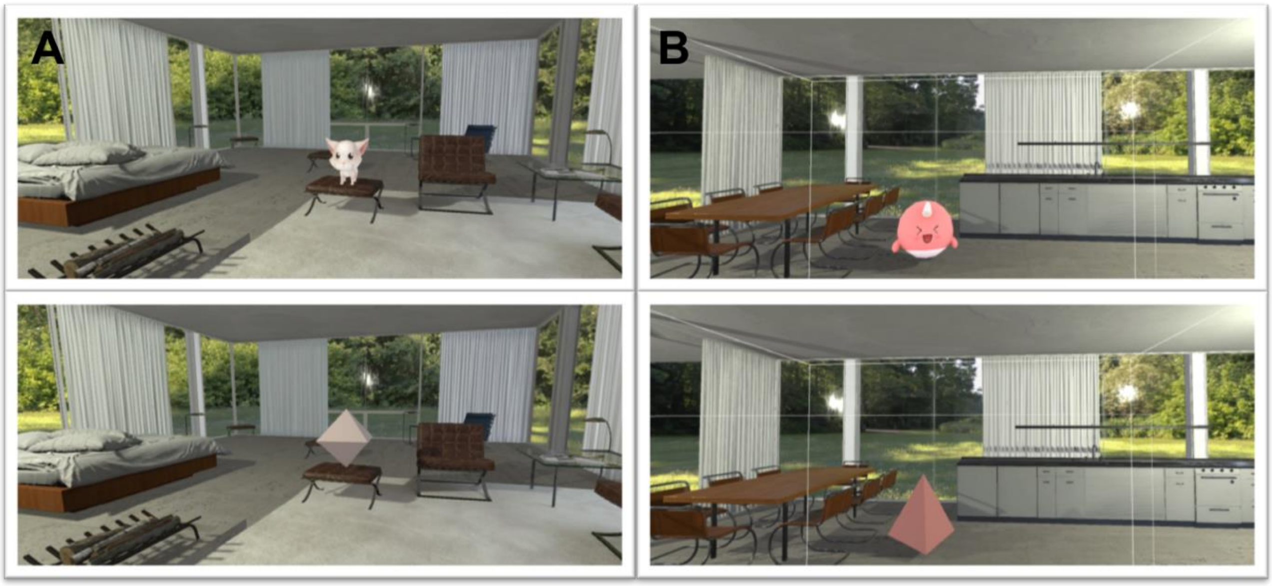

Figure 3: Dynamic VR Task. Participants search and look at appearing stimuli (pet or shape). Pairs of pet (top) and shape (bottom) appear at the same location in the scene on different times A) a cat and a diamond. B) a laughing narwhal and a pyramid.

In our pilot study we found **a differential pattern in the sEMG signal** during presentation of animals compared to a neutral geometric shapes showing stronger signals for the positive emotion inducing stimuli. Figure 4 shows an example of such differential response.

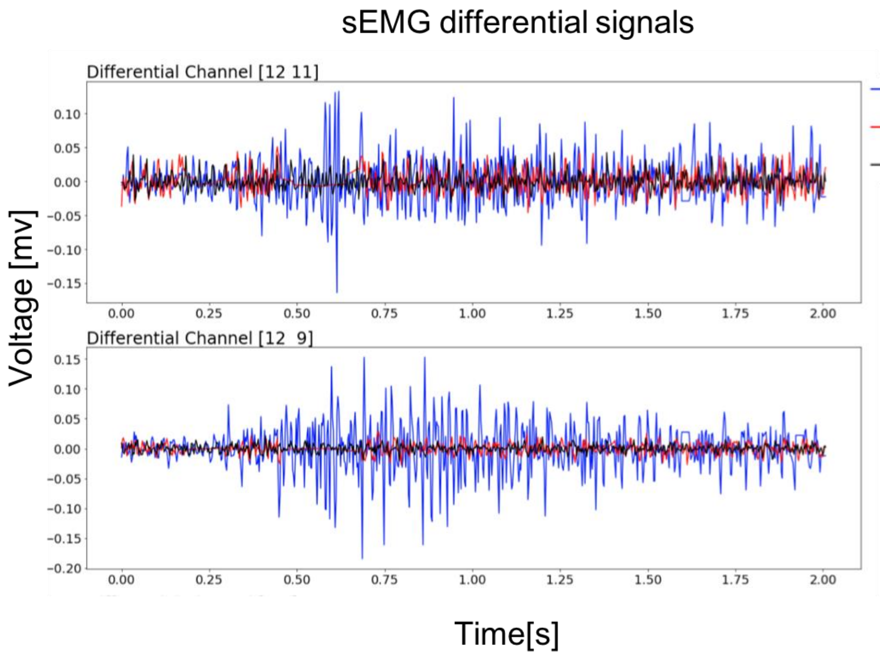

Figure 4: sEMG differential signals while viewing an animal (GoatB – blue line) vs. Cone (red line and the signal during rest (black). Each panel plots a different combination of differential signals which were sensitive to smiling expressions: channels (12,11), and channels (12,9). For channels location refer to Figure 1.

We also obtained gaze tracking and pupil diameter measures from the Tobii-installed VR HTC Vive system (Figure 5). We have one of the first systems delivered worldwide and have been working with Tobii R&D to develop more precise output measures that will fit our aims to allow for as rich as possible dataset.

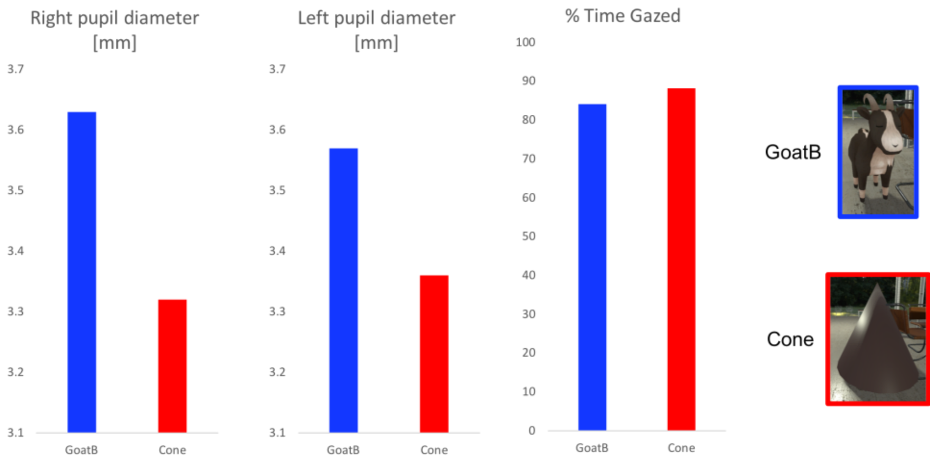

Figure 5: Preliminary eye tracking measures obtained from the Tobii-installed VR HTC Vive. We obtained proportion of gaze as well as binocular pupil diameter measures of two stimuli: one that was highly ranked (goat) versus the cone that was ranked low.

Budget of 1st year : We will use the remaining budget to continue the support of the PhD student and lab technician. We will purchase a professional dynamic graphic design to induce stronger emotions including negative ones. We will produce additional electrodes to allow testing of more participants and hire CS engineers to perform integration of all signal sources towards signal analysis.

Plans for Year 2

In the second year of the grant we aim to achieve our full goal of creating an **individualized closed-loop sensorized virtual reality for behavioral change** towards commercialization of the technology. We will develop the final component linking all the data will be the development of **advanced machine learning algorithms** that will be applied on the rich data from all sensors (electrodes and eye-tracking) to decode the current internal state and then inform the real-time the task presented to participants to enhance learning and behavior.

We will test a full cohort of n=25 participants that will allow to achieve a large enough sample to train and test the ML algorithms. The PhD student will code ML algorithms that combine all signal sources: sEMG electrodes, head-movements, eye-gaze and pupil diameter. We will then recruit CS engineers to finalize the coding of our environment to change the task based on the identified internal states from all sensor sources.

Commercialization process

A preliminary market analysis we performed established the huge market value of the proposed project: The Global Emotion Detection and Recognition (EDR) Market is a robust and growing market which "is estimated to witness a CAGR of 32.7% over the forecast period (2018-2023), driving the market to reach 24.74 billion by 2020. In general, Tractica forecasts that worldwide revenue from sentiment and emotion analysis software will be worth $3.8 billion by 2025. The most likely early market penetration for the subject technology will be the medical and security industries. Some EDR companies operating in the emotion detection and recognition industry are Affectiva, Beyond Verbal, iMotions, Noldus Information Technology, Sentiance, Sightcorp, Realeyes, CrowdEmotion, Kairos AR, Inc., nViso SA., and SkyBiometry. **None of these companies integrated sensors or algorithms into a VR setting with the ability to be AI adapted.**

Entrance into the Global Emotion Detection and Recognition market and specifically the Global Facial Recognition (GFR) niche of this market will be eased with collaboration. We aim to first enter the health sector by partnering with a current VR treatment content provider such as VRHealth https://www.xr.health who have already expressed their interest in our technology.

IPR position and strategy: We plan to file a patent application that will cover the specific utility of virtual reality (VR) and computational methods for detection of individual internal states. We envision that a solution would include a client server system that will assist with protection of our proprietary algorithm.