RESPIRATORY EFFORT AS A POTENTIAL ACCESS PATHWAY

Kelly Tai, Tom Chau
Bloorview Research Institute, Toronto, ON, Canada
Institute of Biomaterials and Biomedical Engineering, Toronto, ON, Canada

INTRODUCTION

Many individuals with severe motor impairments communicate via alternative and augmentative communication (AAC) devices. Due to their low cost and availability, mechanical solutions remain a popular option for those who exhibit sufficient motor control to operate a simple switch device [1]. For example, pneumatic switches ("sip-and-puff") activated by changes in air pressure are used in a variety of communication and control applications.

The respiratory system is unique in that breathing, while regulated by the autonomic nervous system, is also subject to substantial voluntary control. As an access pathway, respiratory effort is of interest for several reasons. Low-cost, non-invasive monitoring methods are commercially available. Sensors are typically attached to the user's upper chest or abdomen with an adjustable belt, yielding no discomfort to the end user. Risk of infection is also substantially reduced. Furthermore, respiratory effort generates a continuous biological signal, potentially facilitating more intuitive control schemes for the end user. Real-time control based on respiratory effort may be a viable option for ventilator-independent individuals. Shorrock et al. [2] demonstrated the use of breath control as a one-dimensional signal to navigate a spelling program.

One drawback that remains with many current access technologies is inadvertent activation. The problem is perhaps best illustrated in access modalities that share a single channel for control and observation; for example, a person using an eye tracker will redirect the computer cursor when he or she reads information from the screen. An analogous issue with respiratory effort would be the inability to distinguish between signals generated by voluntary and involuntary breath control. This problem is exacerbated in the target user population, many of whom suffer from respiratory complications.

The objectives of this preliminary study were to: 1) investigate if an individual's breathing pattern is consistently repeatable; 2) determine if a subset of "voluntary" and "involuntary" breathing tasks can be distinguished from one another.

METHODOLOGY

One able-bodied 24-year old female from the University of Toronto participated in the study.

Protocol

In the experimental protocol the participant was asked to perform a series of breathing tasks in a stationary, seated position. Motion artifact was minimized by restricting body movement. The four tasks of interest were a rapid inhale-exhale, a 5-second breath hold, a yawn, and a cough. Data were collected for each task over a series of shorter trials ranging from 100 to 120 seconds.

Prior to data collection, a 100-second baseline recording was obtained. The subject was then asked to perform one breathing task nine times (with 10 seconds rest between exertions). This procedure was repeated three times (once for each task) with a 2-minute rest period between each trial. The above protocol was repeated until a minimum of 50 samples for each breathing task was obtained.

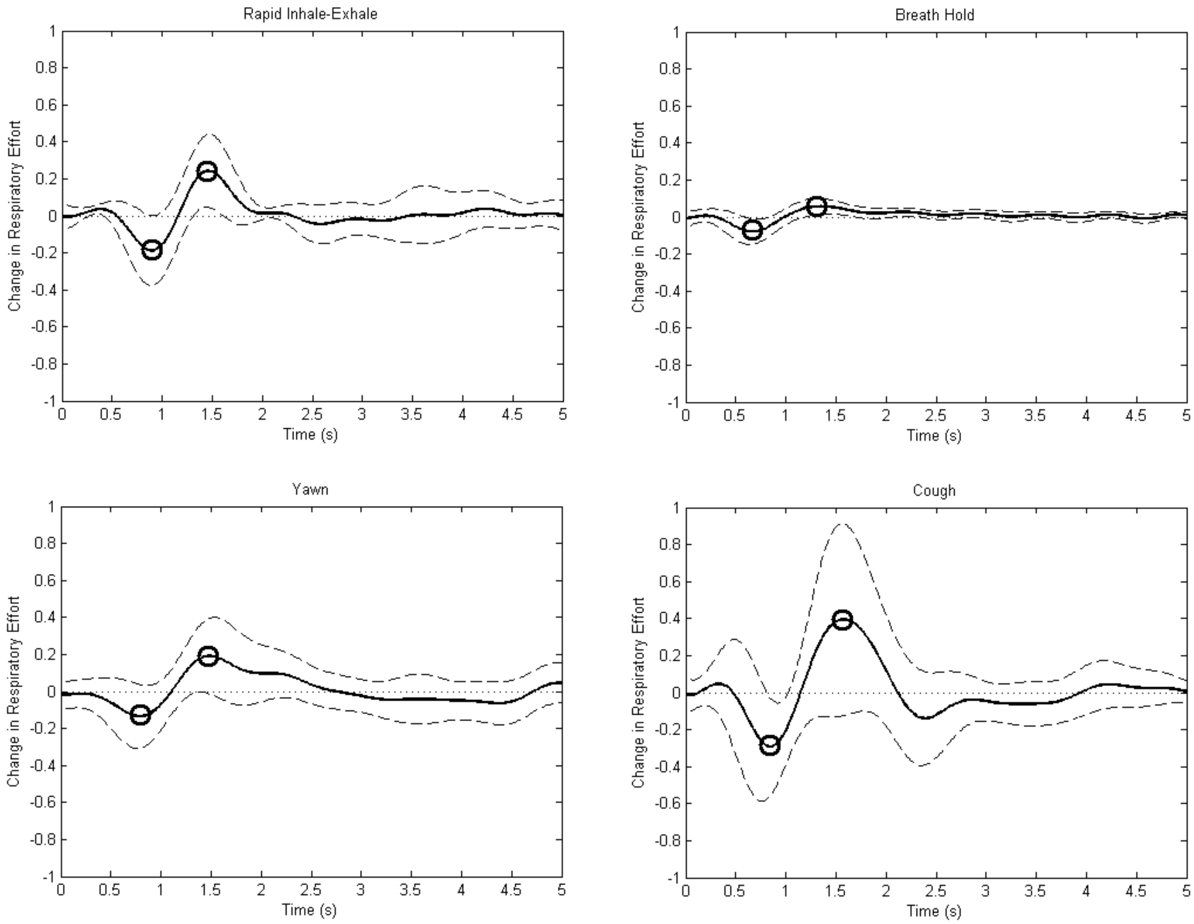

Fig 1. Each diagram captures a 6-second interval of the mean curve for respiration task (where t ≅ 1 represents the negative maximum rate of change in respiration effort). Standard deviation is indicated by the dashed lines. Landmarks of interest are denoted with o's.

Instrumentation

The subject was fitted with a piezo-crystal respiration effort sensor (Grass Technologies) around her abdomen, with the sensor box positioned slightly to the right of midline. Sensor leads were connected to 1 of 16 analog inputs to a Grass Model 15 Bipolar Neurodata Amplifier. A 16-bit DAQ (PCI-6014, National Instruments) was used to sample the amplified input signal at 60 Hz. The digitized data was acquired using LabVIEW 7.1.

Data Analysis

Each sample was normalized by taking its first derivative and filtered through a Butterworth filter of order 2 with pass-band 0.1 – 1 Hz and 0.5 dB pass-band ripple. Figure 1 illustrates mean curves +/- SD for each task. To reduce phase variability, global registration was applied to each set of curves using the technique described by Ramsay et al. [3]. Data were not analyzed to show statistical significance at this point due to the modest sample size.

Two landmarks were found to be common among the four tasks: a local minimum representing the negative maximum change in respiratory effort (corresponding to an inhale), and a subsequent local maximum representing the positive maximum change in respiratory effort induced during an exhale. Paired t-tests were performed on combinations of the landmarks to determine whether the observed differences were statistically significant ($n = 50$).

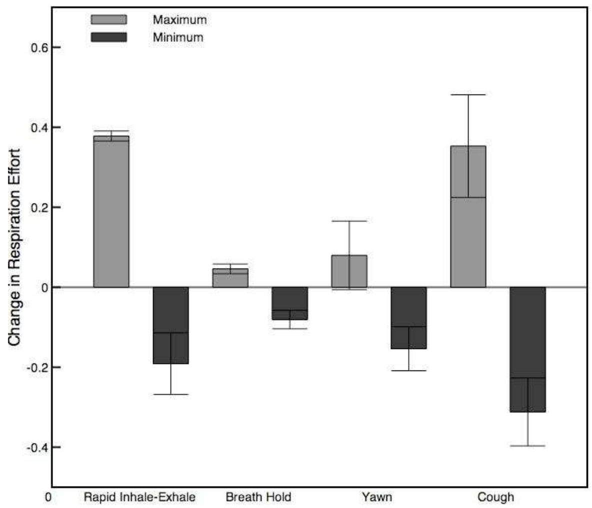

Fig. 2. Results for maximum and minimum changes in effort for voluntary and involuntary respiration tasks.

Analyses indicate that our observations for voluntary tasks were consistent, and could form the basis for a simple on-line classification system. Figure 2 summarizes the results. Local minimum landmarks were mutually distinguishable ($p < 0.01$). All but one pairing of the local maximum landmarks – rapid inhale-exhale and cough – were found to be significantly different ($p < 0.01$).

FUTURE DEVELOPMENTS

The next objective is to continue with data characterization by repeating the experiment on multiple able-bodied subjects and subjects from the target population in order to establish a set of heuristics for signal classification. Our paradigm will also need to be modified to accommodate on-line classification.

CONCLUSIONS

Respiratory effort sensors have the potential to offer several advantages over other breath-actuated AAC devices. We argue that their ability to generate continuous biological signals allows us to address the problem of inadvertent activation. Preliminary data suggest that common landmarks in voluntary and involuntary respiratory task signals can form the basis for an on-line classifier. Eventually, this access channel may also be used to augment other physiological signals to yield a more reliable reflection of user intention.

ACKNOWLEDGEMENTS

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