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WHITEPAPER:

Disambiguating Cough Provenance in Cohabiting Settings

A study demonstrating the use of synchronized wearables to determine when a cough monitor detects non-user coughs

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Abstract

Background: Continuous cough monitoring is increasingly used in clinical and real-world studies. However, in multi-person environments, distinguishing between user and non-user coughs remains a key challenge.

Objective: To evaluate whether relative sound energy, quantified as root mean square (RMS) amplitude across synchronized wearables, can accurately attribute coughs to individual sources.

Methods: Cohabiting participants (n = 4) equipped with synchronized cough-detecting smartwatches performed structured coughing tasks across varied acoustic environments. Cough events and corresponding RMS values were recorded and compared against ground truth annotations.

Results: The cough monitor worn by the source individual detected 100% of coughs with no false positives. The non-source device detected 95% of coughs, also with no false positives. RMS values were significantly higher on the source device (median RMS 0.0925 vs. 0.0235; $p < 0.001$). Using RMS thresholds enabled 100% correct attribution of cough events to the originating individual.

Conclusions: RMS-based analysis of synchronized acoustic signals enables reliable disambiguation of cough provenance in cohabiting settings. This approach enhances the validity of wearable-based cough monitoring for decentralized trials and ambulatory health applications.

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Introduction

Continuous, ambulatory monitoring of health related signals has become possible with recent advances in sensor development, mobile internet and artificial intelligence. Currently the possibilities include vital signs (heart rate, respiratory rate, oxygen saturation), physical activity, stability and sleep quality. On-device microphones allow monitoring of important signals such as cough, but it also raises the issue of potential acoustic contamination in shared environments. For wearables and other form factors without a contact-microphone, there is currently no clear source disambiguation method for coughs detected in multi-person settings. In this white paper we explore the potential for relative loudness across synchronized wearable devices to solve this problem in cohabitating coughers.

Methods

Study design

We invited co-habitating couples to wear synchronized cough-detecting watches (Hyfe's CoughMonitor Suite) and produce solicited coughs in different acoustic environments with varying distances between them. The devices captured the timestamp of every individual detected cough and, simultaneously, its average loudness, expressed as root mean square energy (RMS). Loudness was assumed to be a proxy for distance to the cough source and the acoustic environment.

Data collection

Individuals wore a Hyfe CoughMonitor smartwatch running Hyfe´s fully automated cough-detection software paired with a smartphone app (CoughMonitor Companion). This version of the software running on the watch was modified to capture the RMS (root mean squared energy) of each cough. The audio sampling rate was 8,000hz.

Analysis

Participants were asked to complete a log which included the start time of each cough bout, the person producing each cough and the watch they were wearing at that time. This information was used as ground truth given the solicited nature of the coughs.

The time alignment of each captured cough was compared visually with the coughers' log and the RMS value was assessed for alignment with proximity to the cough source, i.e., higher RMS in the coughs captured by the watch worn by the indicated cougher.

Results

Two participant couples (ie, 4 individuals) took part in the experiment. The 4 participants produced 82 coughs in 2 separate sessions.

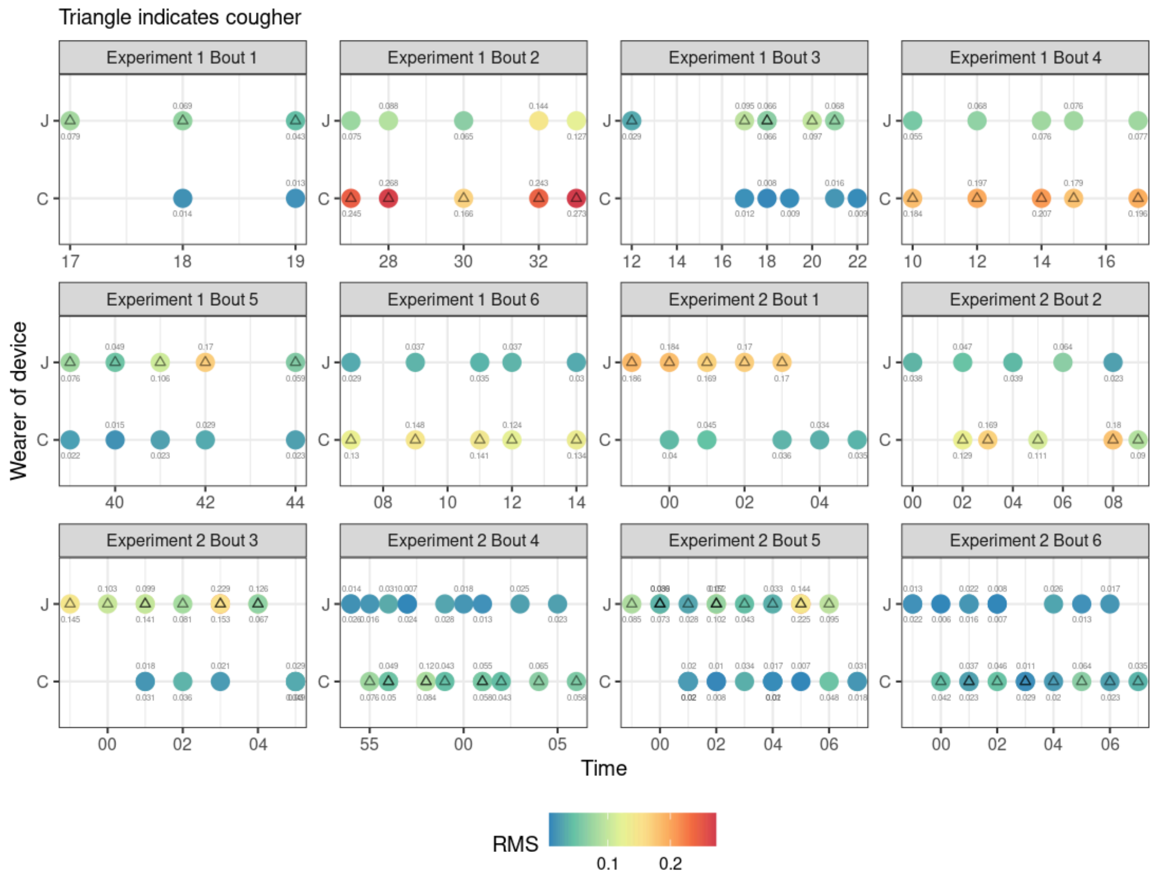

Figure: *coughs RMS by participant (y axis) and time of cough as minute of the hour (X axis)*

The CoughMonitor worn by the source detected 82 coughs (sensitivity = 100%) and 0 false positives. The CoughMonitor worn by the non-cougher detected 78 coughs (sensitivity = 95%) and 0 false positives. 12/12 cough bouts were correctly identified as simultaneously occurring (**Figure**).

The median RMS value was 0.0925 in the watch worn by the cough source and 0.0235 in the one worn by the non-cougher (**Figure**). The mean difference in RMS was 0.0856 (95% confidence interval of 0.034 to

0.12), i.e. the non-cougher had values >90% lower than the cougher, with cough-specific differences ranging from 0.006 to 0.218. This difference was statistically significant with a p value of <0.001 (two-sided T-test).

The RMS value allowed us to calculate the cougher-specific sensitivity of CoughMonitor. When the RMS values were ignored, 95% of coughs resulted in double/simultaneous detections. However, leveraging the RMS values allowed it to correctly attribute 100% of the coughs to its source participant.

Discussion

Key FIndings

The root mean square energy of sound might be an effective method for the disambiguation of the cough source among cohabiting couples. This has important implications for the accuracy of acoustic monitoring:

(1) it allows the use of non-intrusive automatic monitoring, even in one of the most challenging situations, acoustic contamination by a household member
(2) it removes the need for a confirmatory data stream from a contact microphone which in turn,
(3) opens the door for integrated monitoring on a single device such as a smartwatch. Of note, this is a versatile method that works across a range of acoustic environments expected within the household or workplace, and might work on a range of different form factor devices.

Clinical Implications

The ability to accurately attribute coughs to specific individuals in cohabiting environments has significant implications for both remote health monitoring and clinical trials. In longitudinal studies or therapeutic monitoring, particularly for conditions like chronic cough, asthma, or respiratory infections, reliable source attribution ensures data integrity and strengthens individual-level insights. This is especially critical in decentralized trials or real-world evidence generation, where participants are frequently at home and often share living spaces.

Comparison to Alternative Methods

Traditional approaches to disambiguating cough sources - such as contact microphones or manual annotation - can be intrusive, impractical for long-term use, or subject to human error. Contact microphones, while effective, require precise placement and participant compliance, potentially impacting comfort and adherence, in particular over longer periods of time. In contrast, leveraging acoustic energy differences across synchronized wearables offers a passive, scalable, and user-friendly alternative that integrates easily with standard consumer form factors like smartwatches.

Limitations

This method requires the use of an additional device in the household which could increase monitoring costs. The threshold for temporal proximity and additional analysis work is better assumed by a system with real-time results such as the Hyfe CoughMonitor.

Future Directions

There is need for additional work on standardizing the experimental approach, such as by adding decibel meters and pre-recorded sounds as well as to expanding the experiments to additional acoustic environments and real world settings. Future tests should also look at couples sharing a bed. The integration with additional biosignals also opens the door to improved accuracy via this dual channel.

Finally, the conclusions in this paper are based on a relatively small sample of cohabiting couples and require validation in larger, more diverse populations.

Conclusion

Adding an RMS signal and real time monitoring to the partner in a household is a technically acceptable method for disambiguation of potential acoustic contamination.