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Varied facial cardiovascular and spatiotemporal patterns studies using transdermal optical imaging

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Abstract
In human neuroscience research, cardiorespiratory exercises are key markers of several physiological and mental processes. The goal of this the spatiotemporal patterns of cardiovascular activity from dynamic data was the goal of a proof-of-concept research in the face's haemoglobin concentrations. We began by concurrently recording using a digital video camera to study the dynamics of face transdermal blood flow and electrocardiography data with & electrocardiography device. Group independent component analysis (ICA) was then used to separate the video image data obtained from several subregions of a face into independent components. Last but not least, the ICA parts comprising By contrasting, cardiovascular activity was identified. To the ECG, their magnitude spectrum. There were cardiovascular activities. shown to be related with five separate components that indicate diverse Variations in the spatiotemporal dynamics of facial blood flow. The ICA were found in left cheek, left chin, and bilateral forehead, in that order. The data indicate that cardiorespiratory activities have various dynamic features within several facial subregions. Additionally, the most recent discoveries suggest that transdermal optical imaging technology has the potential to be a novel neuroscience tool for studying human physiology and mental process may be studied remotely and without interaction.

Keywords: - *Transdermal Optical Imaging, Spatiotemporal, ECG, ICA*

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I. Introduction:

Important biological signals include the human heart's physiological activity. They are frequently utilised in the study of human neurology because they are practical & trustworthy signs of many physiological and psychological conditions 1, 2, 3. For example, baseline cardiovascular activity is present when your at rest. However, when people are under intense stress, their heart rates rise, and when they are focused, their heart rates fall. Because of this, scientists have developed a number of techniques to gauge circulatory activity in human neuroscience studies. One technique is to visually extract heartbeat signals from beneath the skin. Since about a century ago, people have been aware that light may pass through human skin and reemit since it is translucent4,5. By using optical sensors to externally collect the reemitted light, one can extract variations in the blood flow under the skin. Then, one may utilise the variations in blood flow to measure cardiovascular activity linked with different physiological and mental states due to the blood flow underneath the skin. partners closely with the cardiorespiratory change.

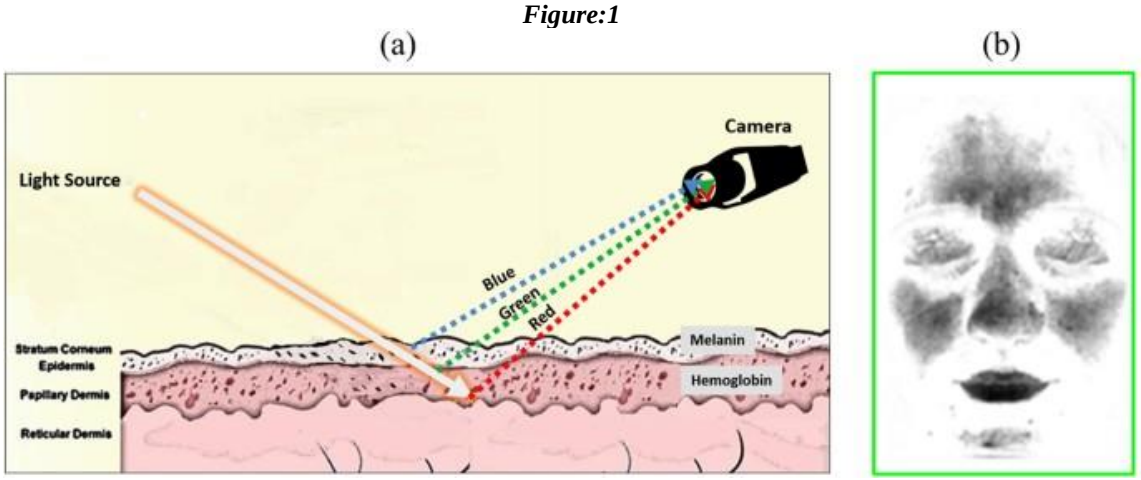
The concept behind photo-plethysmography is a reasonably cheap way to monitor cardiovascular activity non-invasively.

Such diverse spatiotemporal patterns may be shown, which could have significant benefits. For instance, compared to time courses recovered the time course from other regions demonstrates a relatively high signal-to-noise ratio when the cardiac signal is at its highest. Additionally, the province time courses may maintain more subtle and accurate temporal characteristics of cardiovascular signals. which is more significant. As a result, they may be utilised to measure the dynamic characteristics of cardiovascular exercises with greater accuracy.

In this proof-of-concept investigation, the spatiotemporal pattern of cardiovascular activity was examined. In order to achieve this, we employed a cutting-edge transdermal optical imaging technique26 was created expressly capture heart rate readings on the face without being hampered by ballistic heart activity. The above-mentioned transparent quality of the skin is exploited by this technology. Light reemits after passing through various skin tissues, as depicted in Figure 1, and optical cameras can then record this event (Fig. 1a). Melanin and haemoglobin, which each have distinct colour signatures, are the primary chromophores that have

an impact on the light that is re-emitted. In order to best distinguish between the biplanes in pictures that display haemoglobin levels and those that display melanin levels, the TOI approach leverages machine learning.

Figure:1



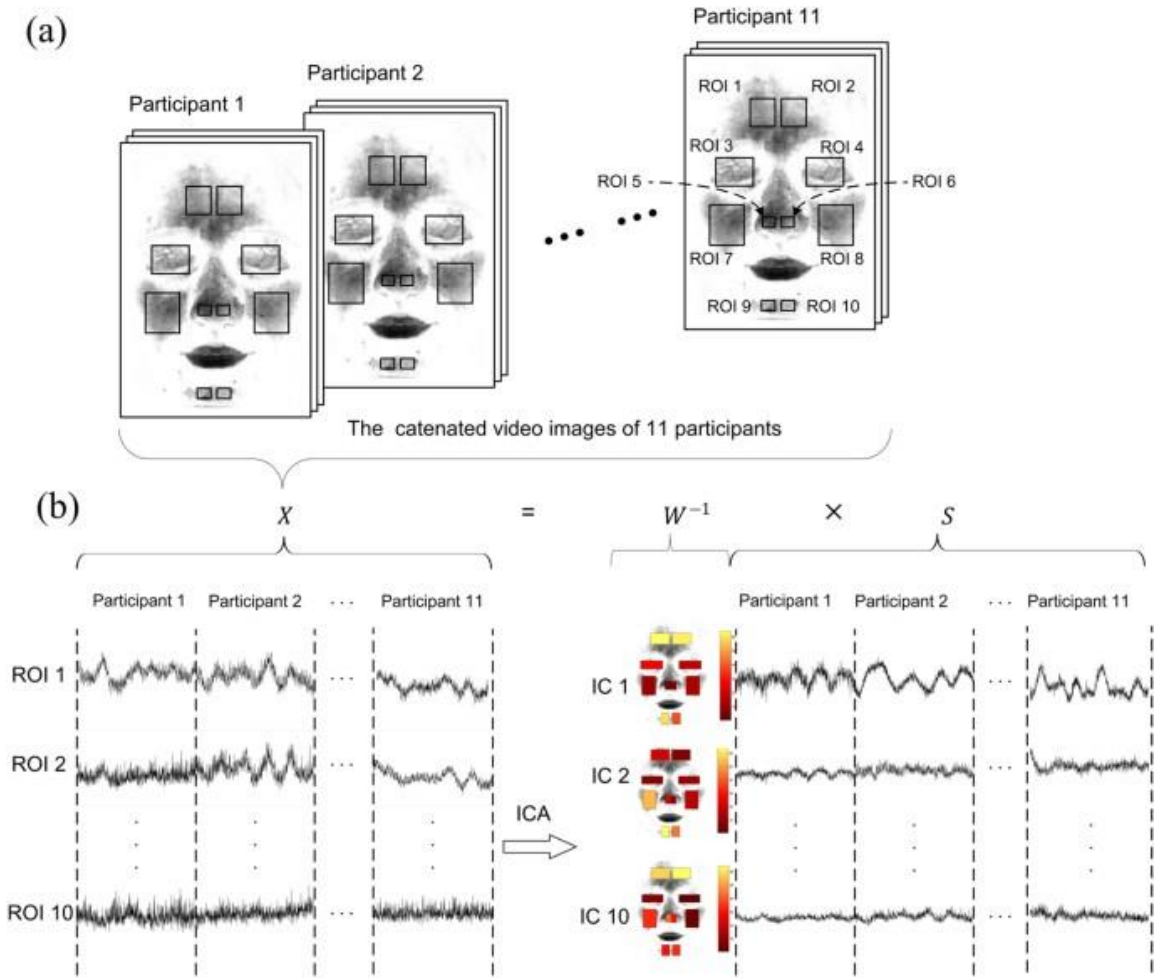
Overview of the transdermal facial image acquisition process in a diagram. (a) Light transmission and re-transmission across various skin tissues. (b) Anillustration of a transdermal facial picture

For these signals, we used independent component analysis to determine their spatiotemporal patterns (ICA). The current study primarily incorporated the temporal change information of haemoglobin concentration and conducted temporal ICA on transdermal blood flow dynamics that were taken from various face sub-regions. ICA was done on the signals of the three colour channels (red, green, and blue), averaged over the full face, in the experiments listed above, but not in these areas. Each separate component produced by ICA should thus include both spatial and temporal information in order to reflect the underlying facial circulatory activity in the sub-regions of the face.

We split face into ten separate areas of interest (ROIs) using transdermal optical imaging technology and gathered face transdermal blood flow data showing the time-dependent cardiovascular activity in various ROIs (Fig. 2a). We selected these ROIs based on the findings and the face vascular anatomy for different types of brain modulation of the facial vasculature. We pooled the picture values on each bit plane for every channel to produce the raw temporal information for each channels in each of the ROIs. This reduced the data dimension while increasing the signal-to-noise ratio.

Figure: 2

ICA schematic for the group, in general. (A) Ten sites are used to create concatenated time courses that include the transdermal face blood flow. of interest and combined with the head-to-tail video images of 11 people. (b) The extended version of Equation 3 is the group ICA. As shown in Each row of the left column represents the concatenated time courses of 11 individuals who were initially taken from each of the 10 facial ROIs, as shown by the corresponding row of Matrix X in Equation 3. Each independent component that has been separated from the original concatenated time courses has two traits, namely the temporal dynamics and the geographical distribution (i.e., the left column). Each independent component's concatenated temporal dynamics throughout each row of the column to the right are shown.

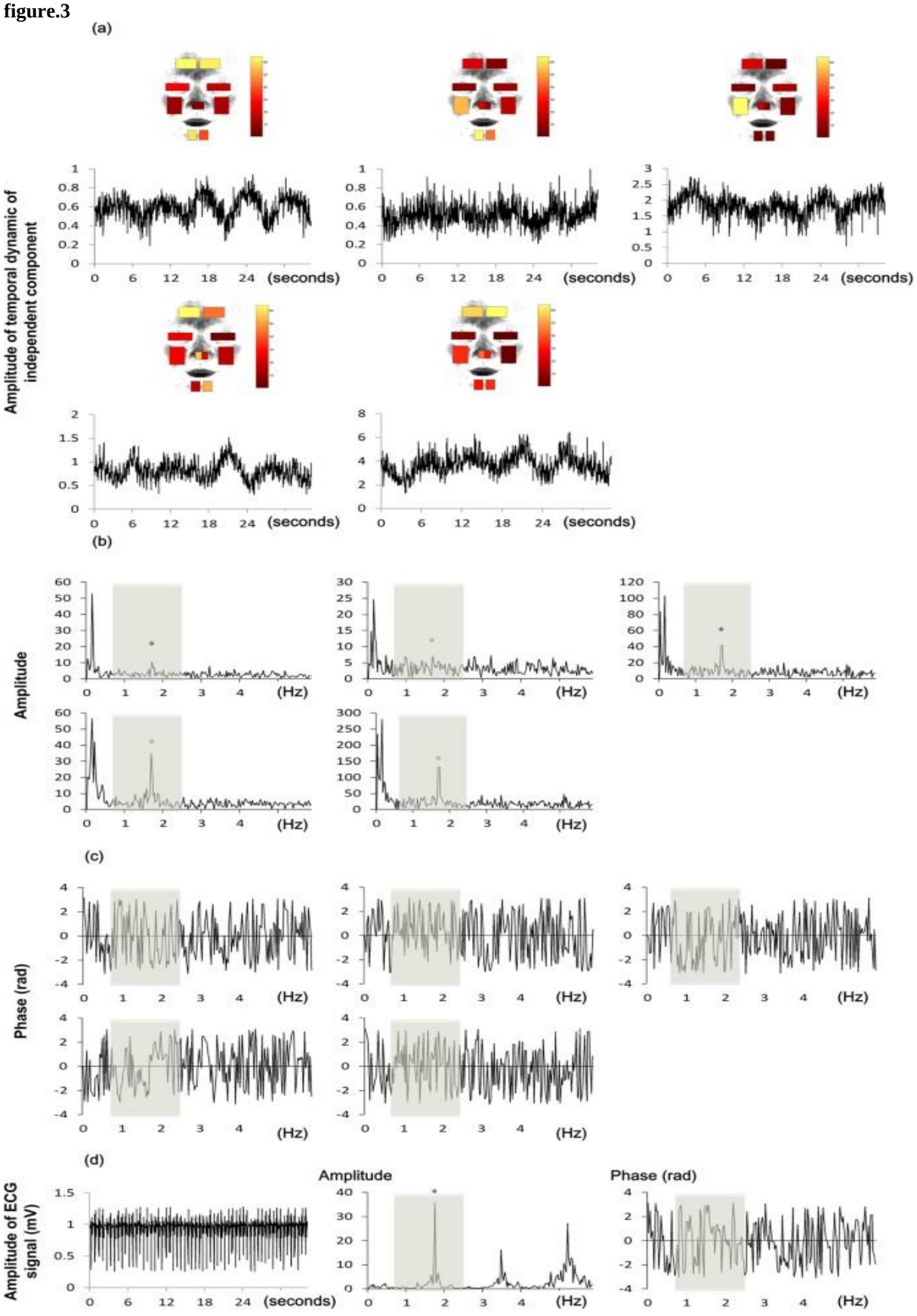


Each independent component's spatial distribution is represented by its corresponding column in matrix W1 in eq. 3.it would be observed each each element has same spatial distribution throughout all of the temporal kinematics of its concatenated time points .

The colour map shows the spatial distribution of strength that is projected onto various ROIs of a face from a component's autonomous temporal behaviour An independent component's temporal dynamics are projected into this ROI with greater power the ROI of its geographic distribution is more yellow.

II. Results

figure.3



In Figure 3, the results of data analysis for one person are displayed as an illustration. These results may be seen in the absorption spectra and phase spectra of the five separate components (Fig. 3a), as well as in the Electrocardiogram (Fig. 3d Left) and its respective magnitude spectrum and phasing spectrum.

the group ICA findings of a sample participant. (a) For this participant, the unique Each separate component's geographic distribution and temporal dynamics. The concatenated terial are different from the individual temporal dynamics of the corresponding independent components, it should be emphasised. The colour map shows the spatial distribution of strength that is projected onto various ROIs of a face from a component's autonomous temporal dynamics An independent component's temporal dynamics are projected into this ROI with greater power. The ROI of its geographical distribution is more yellow. (b) The range in amplitude of each temporal dynamics (c) Each person's temporal dynamics phase spectrum d) The magnitude spectrum, phase spectrum, and time course of an ECG signal captured at 200 Hz and resampled to 20 Hz (right). The shaded area denotes the 0.7–2.5 Hz frequency range.

III. Discussion:

The present study utilised a common digital camera to accurately, noninvasively, and remotely reveal facial cardiovascular activity. We did this without touching the face with any sensors by using a contactless method. Furthermore, we demonstrated that the cardiovascular activity had distinct multiplanar The present work, to the finest of our knowledge, is the characteristics in each of the various facial sub-regions. based on the kinetics of transdermal blood flow, provided insight on the spatiotemporal aspects of face cardiovascular activities.

IV. Conclusion:

In conclusion, the current study extracted data on blood flow in several facial regions using a conventional A tearing transdermal optical imaging method with a digital recorder. We found that variations in facial blood flow can be reflected by five separate components that represent different spatiotemporal dynamics were related to facial cardiovascular activities. Our findings imply that human physiological and psychological processes may be studied using differential spatiotemporal dynamics. In a broader sense, the current findings also suggest that transdermal optical imaging technology has the potential to become a new non-invasive, low-cost neuroscience tool for studying human physiology and psychology.

V. Materials and Methods :

- **Participants:**

Eleven healthy participants in the current study (5 men and 6 women, both aged 30.59.43). None of them took any drugs that would have affected the blood flow to their faces. The University of Toronto's Research Ethics Committee authorised the current investigation, and all procedures were completed in accordance with the applicable laws and norms. Prior to taking part in the trial, participants gave written informed consent.

- **Experimental setup:**

To obtain transdermal pictures in this investigation, we utilised an Allied Vision Technologies Pike F-421 camera. The participant's face was around 50 cm away from the camera, which was taking video images at a rate of 20 frames per second at a resolution of 910 800. Two LED lights served as the lighting source. When tested in a laboratory recognised by the National Voluntary Facility Accreditation Program (NVLAP), the luminous flux difference between the lights was less than 0.15%.

- **The Experimental approach and data collection**

The experiment was carried out in a dimly lit space. Individual tests were administered to participants. Participants were told to close their eyes during the experiment. Sit motionless, and refrain from thinking about anything specific. For two minutes, their faces were captured on camera. An electrocardiogram was also collected simultaneously at 200 Hz using a BIOPAC Systems Inc. MP150 analogue/digital data gathering system with ECG100C amplifier.

Data Pre-processing

The capture of transdermal pictures and intensity normalisation were both conducted utilising unique software created in MATLAB during data preparation.

- **Transdermal forehead blood circulation image capture**

As mentioned earlier, we initially gathered full-colour video images of the participants' faces. The first 1024 pictures were picked (about 51 seconds) for each participant and ran the analysis as follows. In the transdermal face photos, we designated ten sub-areas(on both sides of the face, the forehead, eyelids, nose, cheeks, and chin were used as ROIs) (Fig. 2a).Then, using the transdermal optical imaging technology26, a transdermal image of each facial ROI was obtained from each frame of the movie. Each pixel in the transdermal image contained data

on the amount of haemoglobin present under the skin's surface of the face at a certain moment. We then used the greyscale intensity of this transdermal picture to index haemoglobin.

- **Time course extraction and normalisation of intensity**

We next used the average pixel intensity across all ROIs for each participant to standardise the mean time course of this ROI (Equation 1). The grand mean was calculated by averaging the intensity over all 10 ROIs' pixels at all time points.

$x'(i)=x(i)\mu\mu=1N\sum 10i=1\sum Nij=1\sum 1024k=1tijkN=1024\sum 10i=1Nix'(i)=x(i)\mu\mu=1N\sum i=110\sum j=1Ni\sum k=11024tijkN=1024\sum i=110Ni$

where Ni denotes the number of pixels in the ith ROI and x(i) is the mean time course of the ith ROI. For a certain participant, tijktijk denotes the intensity ofthe ith ROI's kth time point of the jth pixel. The purpose of intensity normalisation was to eliminate the inter-individual variation in picture intensity that might be brought on by variations in skin tone, colour, or other optical characteristics.

The initial time courses, which would be employed in the next spatiotemporal analysis, were all 10 of the normalised mean time courses from the 10 ROIs.

- **Analysis of the face cardiovascular system in space and time**

*Analysis of temporal independent components

*ICA is a method for dividing multivariate signals into a number of statistically independent components that is computationally blind.The two qualities that each independent component has are used to characterise its dynamic behaviour and geographical distribution. Furthermore, the points in showsthe separate component's temporal dynamics (IC)share a consistent spatial distribution.

The goal of ICA is to recover the signal of the main components, S, from their linear mixes, X. It is critical to identify a piecewise matrix, W, that defines the filtering that may be used with this approach.$S=WXS=WX$

Equation 2 can be changed to the following form to more accurately describe the spatiotemporal characteristics:

$$\mathbf{X=W-1SX=W-1S}$$

The ith row of this m by n matrix, X, displays the time courses that were first measured (For example, consider the temporal history of one of the face ROIs in the current study). The ith row of S is a m by n matrix, and it showsthe ithseparate component's temporal dynamics (IC). The ith column indicates the relative projection powers of the ith separate component's temporal changes. W1 is a m-by-m mixing matrix. In other words, we may determine where this independent component can be best represented by looking at the ith column of W1, which reflects the geographical the ith independent component's distribution.

- **Independent component analysis for groups of time**

The absence of an ordering of deconstructed independent components is widely recognised. Therefore,group statistics across all participants, conclusions are impossible if we do ICA for each person independently. We resolve this problem using a group ICA technique as a result. Group inferences may be made with this approach since it extendsthe group level with the ICA method. Group ICA has been widely used in the processing of numerous imaging data modalities because of these advantages.incorporating functional magnetic resonance imaging (fMRI)39,40,41 and electroencephalogram (EEG)36,37,38.

The time sequence that was initially recovered from several individuals for each ROI was first concatenated head to tail, as seen in Fig. 2According to Equation 3, the ith row of X thus exhibits the concatenated time histories of all individuals for the ith ROI.(Left column of Fig. 2b The Fast ICA algorithm42 is then applied, On these ten concatenated time sequences, the temporal ICA was run. We then have 10 distinct components withtemporal dynamics that have been concatenated, theoretically. The ith column of W1 reflected the ith independent component's spatial distribution, revealing whichAn unique element was presented on the face ROIs., whereas the ith row of S displayed the ithunique component's temporal dynamics (Fig. 2b right column) (Fig. 2b centre).

Data Availability:

The dataset used in this work is accessible upon reasonable request from the corresponding author.

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