GLOBAL INNOVATION EXCHANGE

Contactless Focus Detection of Meditation through Video

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9/7/2020
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table of contents

1 background

what is meditation?

Human beings are constantly in three different states of consciousness- waking, dreaming, deep sleep. The meditation process takes the mind from the outer realm of the objective world to the inner realm of the inner faculty [1].

why meditate?

Psychological stress, particularly persistent psychological stress, can negatively affect one’s health. Stress triggers physiological responses encompassing changes in the nervous and immune systems, such as an increased level of circulating inflammatory factors . Meditation is an effective method at combating psychological stress. [2]

monkey mind

A common metaphor within the meditation world is that our minds are monkeys, swinging from thought to thought.

the act of meditation

The act of meditation is when you notice your mind wandering, and bring your attention back to the object of focus.

1 background

how many types of meditation are there?

There are many types of meditation: Contemplation, **Concentration**, Use of nature sounds such as the ocean, Guided meditation, Meditative movement exercises such as Yoga and tai chi, qigong, **Breathing exercises**, and Mantra [1].

what meditation will this research focus on?

This research will focus on **breathing meditations**. The are two main reasons for this. First, there is research on these types of meditations already. Second, breathing meditation has shown to change more signals that the body produces, such as heart rate [3].

physiological effects

Reduced blood pressure, heart rate, lactate, cortisol, and epinephrine; decreased metabolism, breathing pattern, oxygen utilization, and carbon dioxide elimination[1].

why breath centered

The breath is one part of the parasympathetic nervous system that we can control. As such, it influences the how the body functions more directly [4].

2 problem

new meditators are unsure

New practitioners of breath-centric meditation don't know if they are meditating correctly when they learn it as a new skill.

new meditators' minds wander

New practitioners' minds wander more often than experienced meditators, and they daydream or get distracted more easily.

new meditators' focus

experienced meditators' focus

3 current solutions

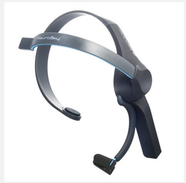
The two types of solutions to help new meditators include app-based solutions and hardware-based solutions. They each have their benefits and drawbacks.

App-based

Pros: Easily accessible, free or low cost

Cons: Cannot give feedback to user, so the user cannot easily tell when they begin to become distracted and daydream

Hardware-based



Pros: Can give feedback to user in real-time to bring their awareness back to the meditation when they start to daydream, by reading brainwaves

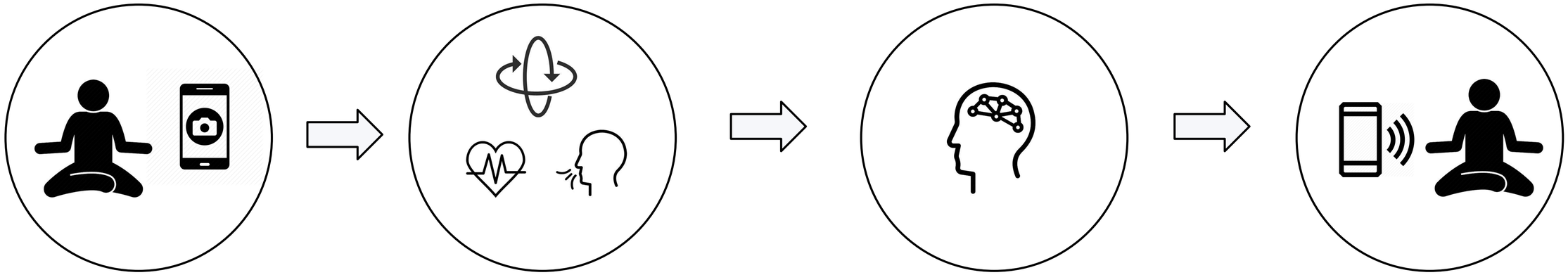
Cons: Less accessible, bulky, expensive

Can there be a contactless way to give feedback and merge these solutions?

4 proposed solution

A contactless feedback system to detect if the person is meditation vs daydreaming/distracted. **This is novel, in that will not use actual hardware**, rather Machine Learning running on the smartphone.

For new meditators, it's hard to notice when they are daydreaming or distracted. **If we can help to shorten the daydreaming time, can they learn to meditate quicker and be more efficient with their time?** We can leverage machine learning to differentiate these two status and remind the user in a real-time feedback manner.



Meditator

The meditator sits in front of the smartphone camera

Extract Features

Use existing machine learning to extract movement, heart rate and breathing rate

Predict Mind State

Predict focus vs distraction based on a new classification model using on the features

Real-time Feedback

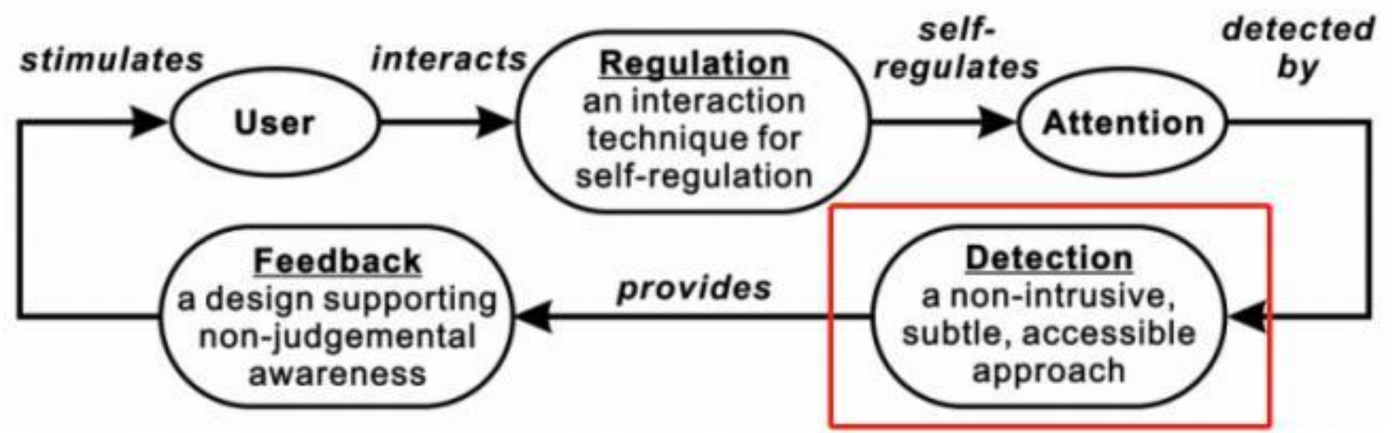
Give a gentle reminder to the user that they need to focus on their breath

5 specific contribution

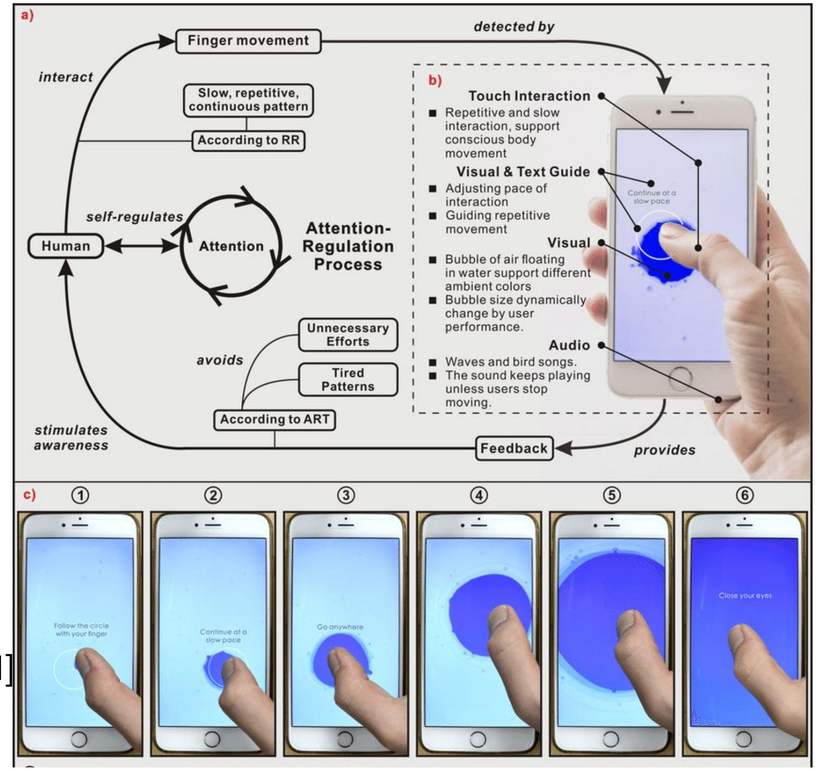
There has already been some research into interactive mindfulness meditation using an attention-regulation process [11].

The closest technique used an app that required users to touch a smartphone in a smooth, repeated fashion.
If the user was found to deviate from the slow pace, the sounds of birds and waves would stop (the feedback).

The specific contribution of this work will detect the meditation without the need for physical contact with a device.



Schematic of the Attention Regulation Framework [11]



6 data collection method

By classifying a video of someone meditating on whether they are distracted or focusing using meditation experts (myself + the muse headset), we can feed that into a ML model. Less movement, more regular breathing.

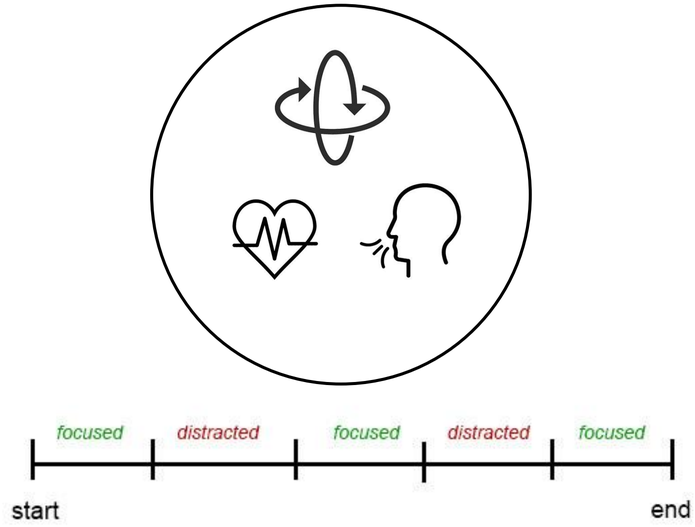
Focused

Less movement, regular breathing

Distracted

Movement, irregular breathing

Classification



Can use this to classify focus vs daydreaming/distraction

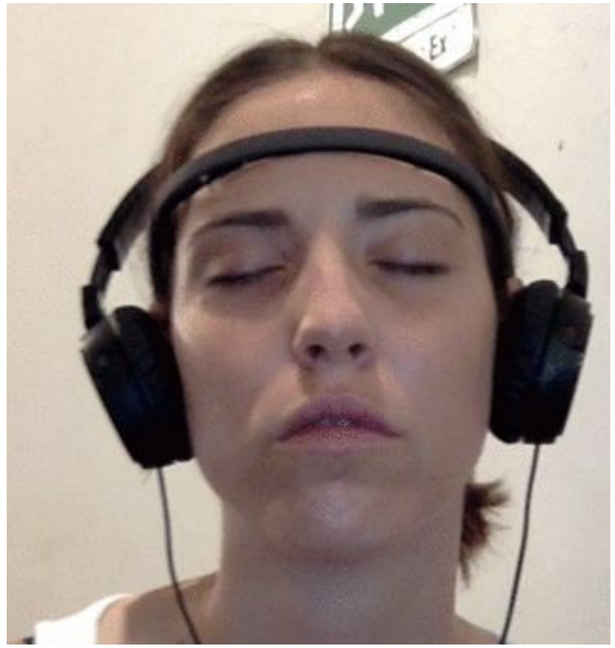
6 data collection method

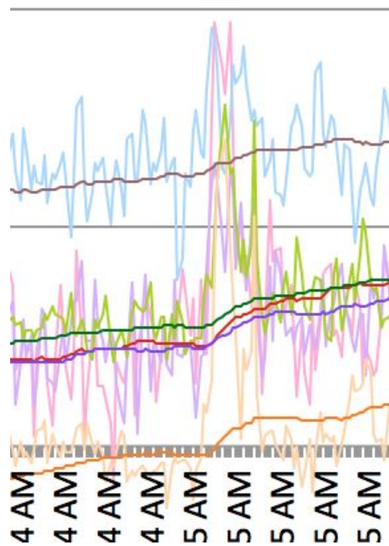
10 minute mindful breathing meditation

Collected data with the Muse headset

Collected video via laptop

12 participants, various ages, genders, and meditation experience





processing and labelling data

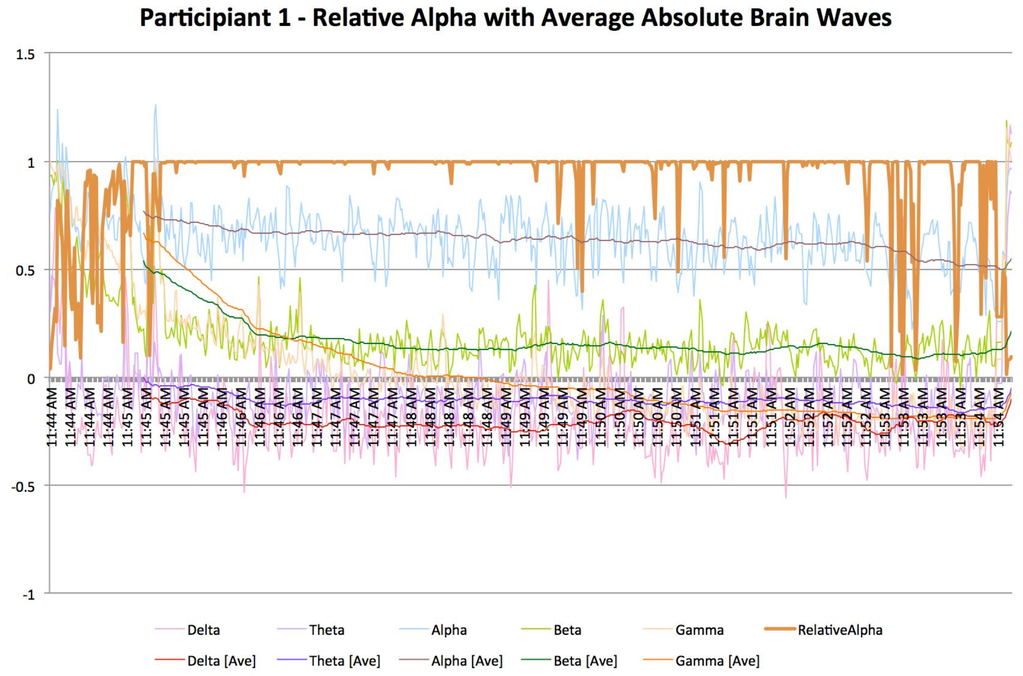
Meditating: when relative alpha waves are higher than the rest

Distracted: when relative alpha waves are mixed with everything

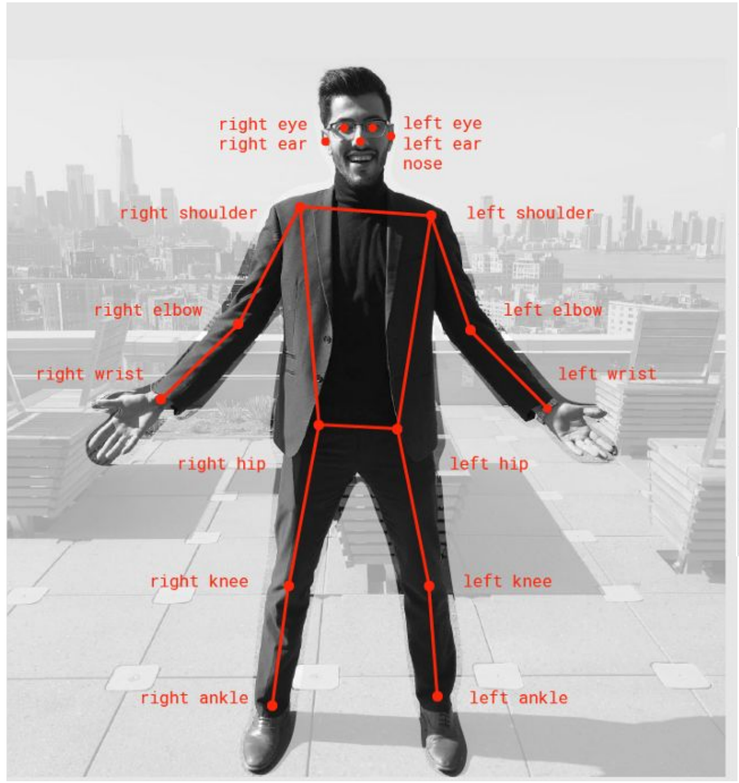
Distracted: spikes in delta waves

Total of 149 focused and 142 distracted clips

6 seconds per clip



7 machine learning model



Id	Part
0	nose
1	leftEye
2	rightEye
3	leftEar
4	rightEar
5	leftShoulder
6	rightShoulder

posenet

14 pieces of data - x, y location of nose, eyes, ears, shoulders

On my mac laptop able to get 14 frames/second

On the iPhone XR only **2.35 frames/second**

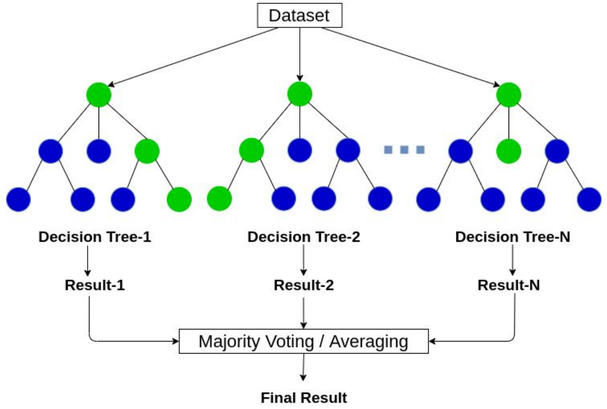
6 seconds per clip - 196 pieces of data (~14 frames x 14 x, y data points)

failed attempts - time distributed layers

A variation of a convolutional neural net (CNN)

Not much success - high variation in accuracy - 70-80%

the winner - random forest



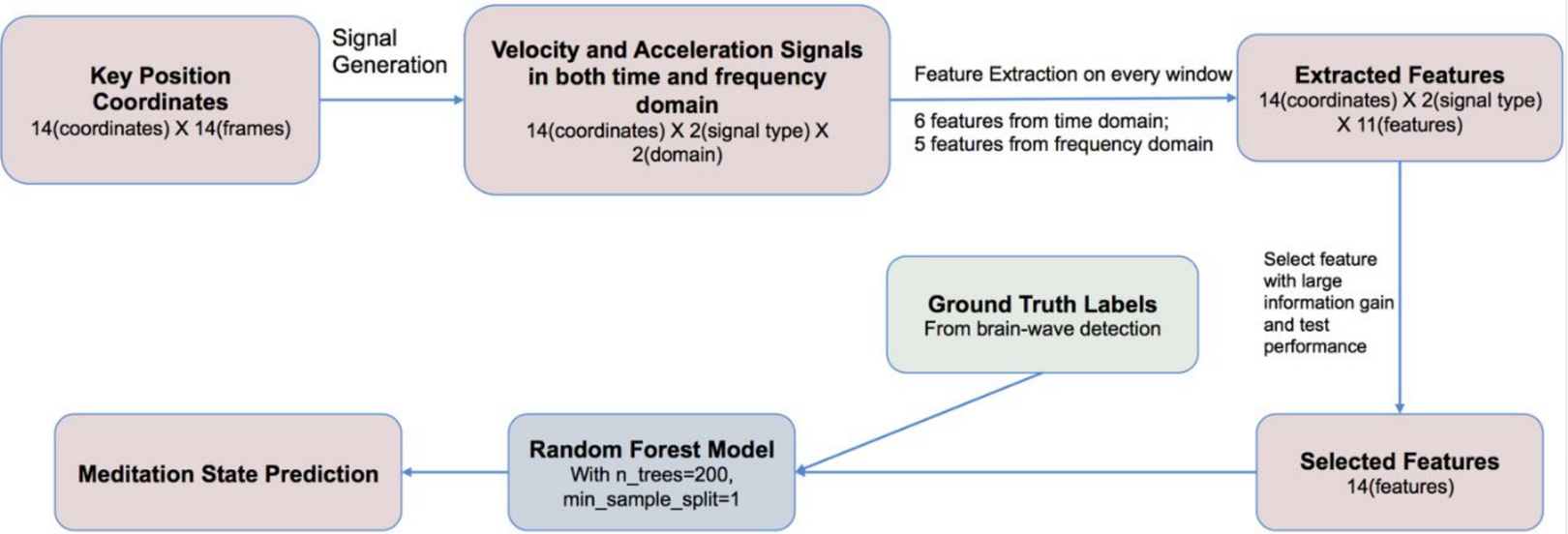
Higher amount of accuracy (91%) - cross user validation

Take the velocity and acceleration of each data point - normalize data using eye distance

Also do a fast fourier transform to find the frequency domain signal for the time signals

Was able to due feature reduction to find the most important features and reduce computation time

7 machine learning model



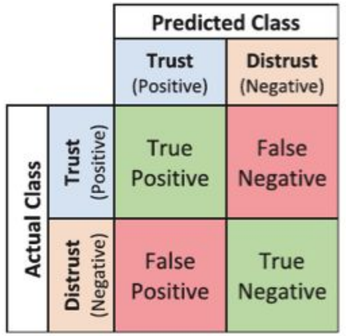
Model Data Flow

Feature	Time domain	Frequency Domain
Mean	√	√
Standard Deviation	√	√
Median Absolute Value	√	√
Kurtosis	√	√
Skewness	√	√
Maximum Value	√	

Feature Extraction

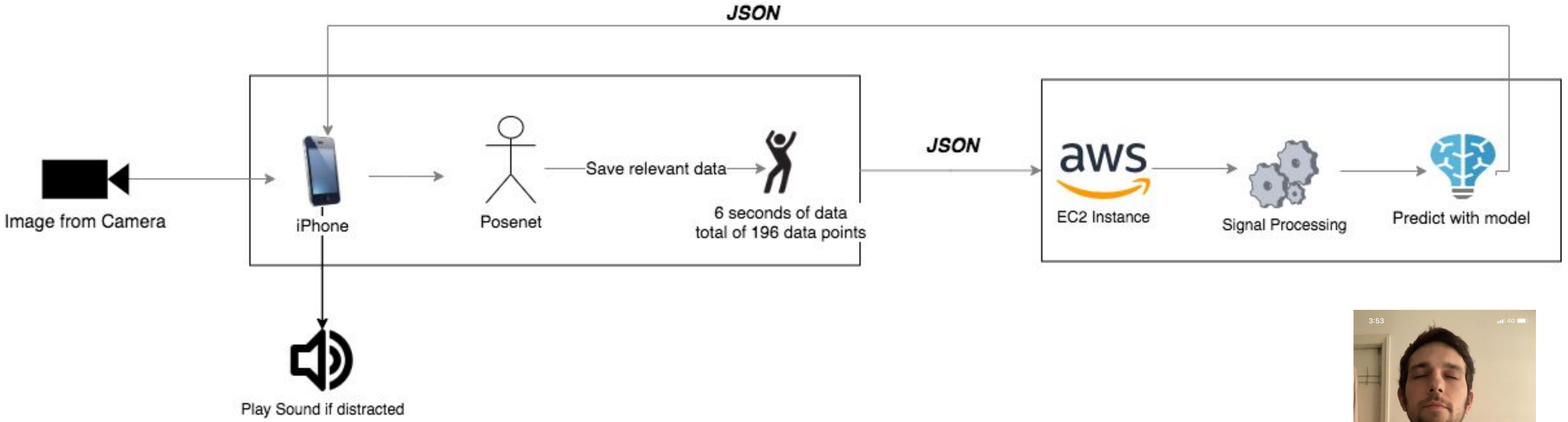
Nose velocity				Right eye velocity				Right ear velocity				Right eye acceleration	
Time domain signal		Frequency domain signal		Time domain signal		Frequency domain signal		Time domain signal		Frequency domain signal		Time domain signal	Frequency domain
STD	MAD	STD	MAD	STD	MAD	STD	MAD	STD	MAD	STD	MAD	STD	MAX.REAL

Selected Features



Confusion Matrix

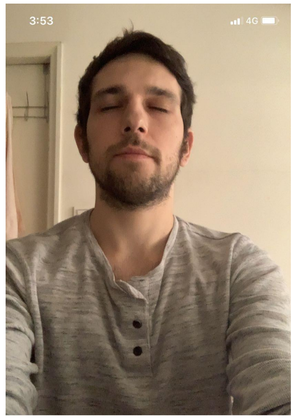
8 hardware/software setup



app built in expo.io

A react native framework that allows for pushing to the web, android, and iphone simultaneously

Some logic on when to play the sound - don't want to overburden the user with constant sounds and to reduce false negatives. 3 distracted predictions in a row are needed to trigger feedback.



9 user study

goal of the study

1) Test efficacy of model by comparing Muse data
2) Test efficacy of feedback on meditation performance

participant and apparatus

14 participants, various ages between 25-35 and mostly new or inexperienced meditators

A meditation app that will guide the users through a breath-centric meditation.

Two different groups - one in Beijing (iPhone 8), one in Taiwan (iPhone XR)

user experiment procedure

The meditation app will have two versions, A with feedback, B without feedback.

Out of lab experiment, participants will be invited to come to a quiet place to meditate.

Also will wear the Muse headset to allow collection of brainwave data to determine efficacy of the algorithm

4 sessions. Version A (7 mins) + Version B (7 mins), 5 min break then Version A (7 mins), Version B (7 mins)

evaluation method

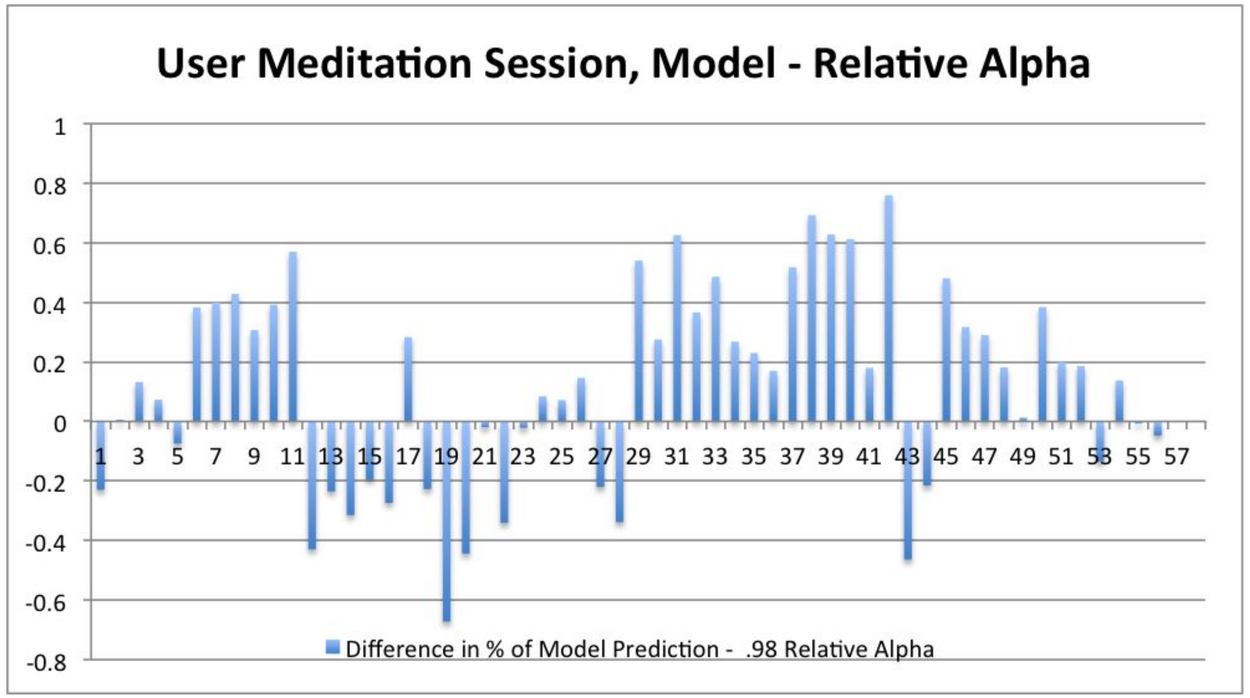
A/B between subjects.

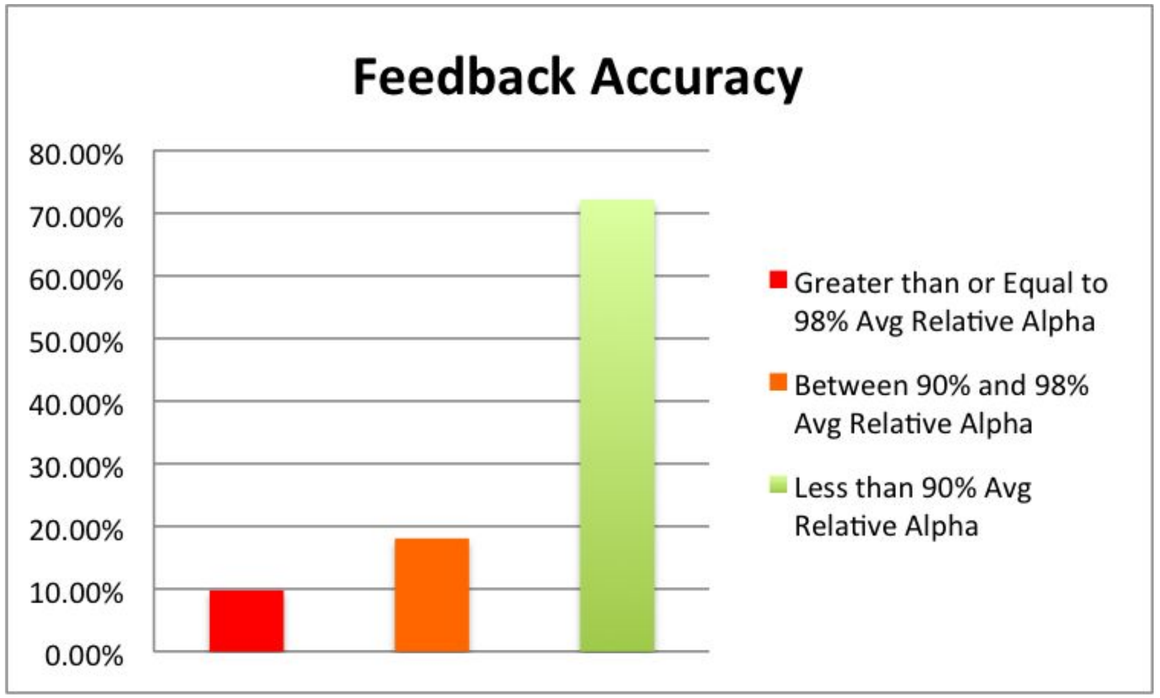
Meditation questionnaire after each session to determine the level of their meditation.

10 results

efficacy of the model - 58 sessions recorded

- In terms of total predictions, the model was accurate within 70% in predicting the brain state compared to the ground truth data from the Muse.
- In terms of giving feedback, the app played the sound when users were not in a high state of relative alpha 90% of the time.
- 70% of users thought the app was ”often” or ”always” correct about when it gave the feedback sound.

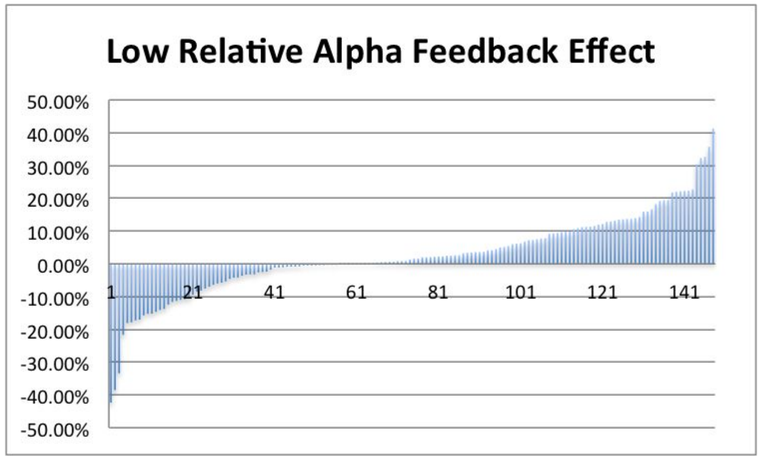


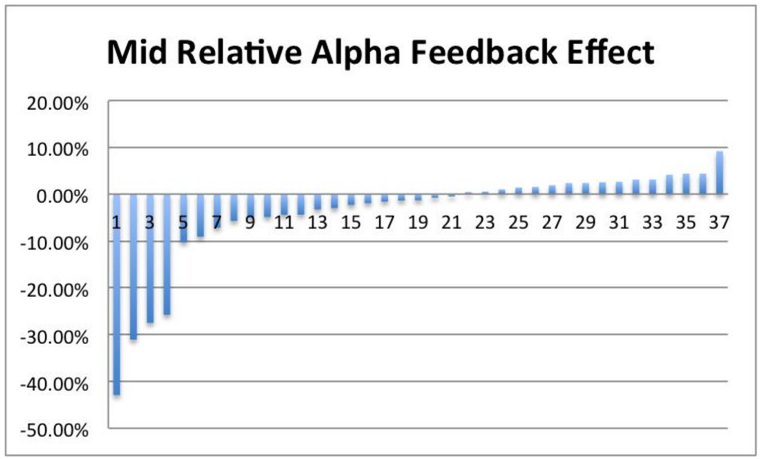


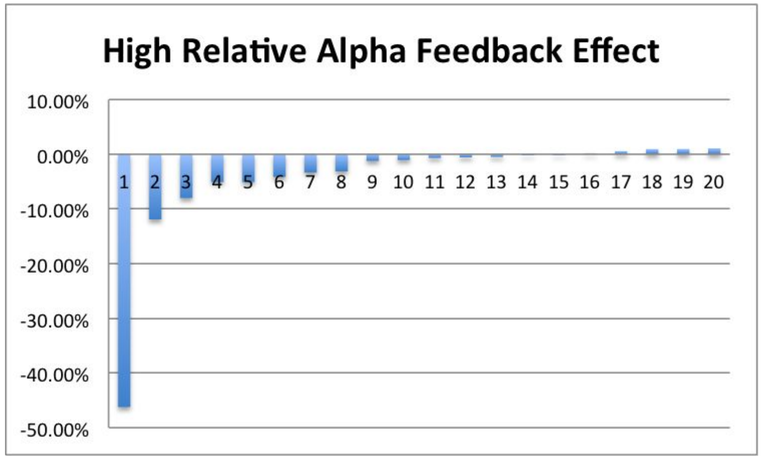
10 results

efficacy of the feedback - 28 sessions with feedback, feedback given 205 times

- For participants in **low** relative alpha the feedback on average increased their relative alpha following the feedback.
- For participants in a **mid** relative alpha the feedback had little effect, except for a few cases where there was a significant drop after the feedback.
- For participants in **high** relative alpha, giving the feedback had a negative effect for the most part.
- In aggregate, it helped improve relative alpha 56% of the time after the feedback was given.
- 60% of participants said they would have preferred to have feedback rather than not have feedback.







11 discussion

type of feedback

- Some participants had an strong, adverse effect to the feedback sound
- Giving participants an option to choose the type of feedback will be allowed in the future

false negatives

- When the feedback sound was given while participants were meditating, it had a mostly negative effect. Further safeguards to prevent this would be useful.
- Adding an additional classification may be useful - neutral mind

iPhone XR vs iPhone 8

- The iPhone XR was able to get 2.35 frames a second for posenet.
- iPhone 8 was able to get 1.8 frames a second.
- This definitely had an effect on the model, as the iPhone XR most often underestimated meditation duration, while the iPhone 8 overestimated it.
- Could also be due to the two different set of groups of people tested by iPhone XR and iPhone 8.

11 discussion - future work

preparing to submit to CHI 2021

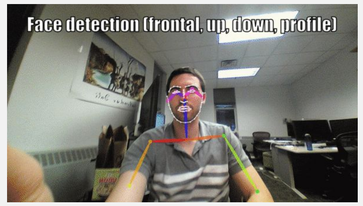
Working to change the paper and get it ready for CHI 2021.

Another user study will be done with a further refined model.

Heart rate and breathing data will be used as further ground truth in this iteration.

Movement

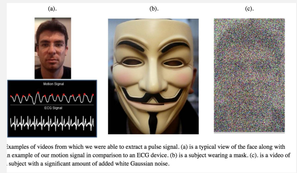
OpenPose - CMU Perceptual Computing Lab [5]



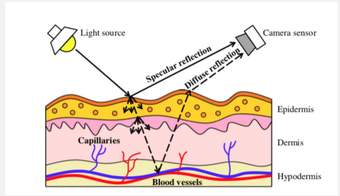
PoseNet - Tensorflow / Google [6]

Heart Rate

Motion-based: Detecting Pulse from Head Motions [7]

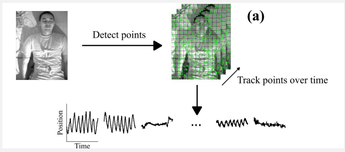


Remote Photoplethysmogram [8]



Breathing

A non-contact vision-based system for respiratory rate estimation. [9]



A simple, remote, video based breathing monitor [10]

12 references - thank you - stay healthy

[1] Meditation: Process and effects (2015)

[2] Is meditation always relaxing? Investigating heart rate, heart rate variability, experienced effort and likeability during training of three types of meditation (2015)

[3] Meditation Breath Attention Scores (MBAS): Test–Retest Reliability and Sensitivity to Repeated Practice (2012)

[4] Heart rate dynamics during three forms of meditation (2004)

[5] OpenPose

[6] PoseNet

[7] Detecting Pulse from Head Motions in Video (2013)

[8] An open-source remote heart rate imaging method with practical apparatus and algorithms (2019)

[9] A non-contact vision-based system for respiratory rate estimation (2014)

[10] A simple, remote, video based breathing monitor (2017)

[11] A Framework for Interactive Mindfulness Meditation Using Attention-Regulation Process. (2017)

6 the plan

Gathering videos of new meditators doing a 10-minute breathing meditation. N=3 at the moment, hoping to get at least 10, if not more.

With the features and classification, can verify the model and compare it to the ground truth data.

Gather data	Extract features	Verify model	Test

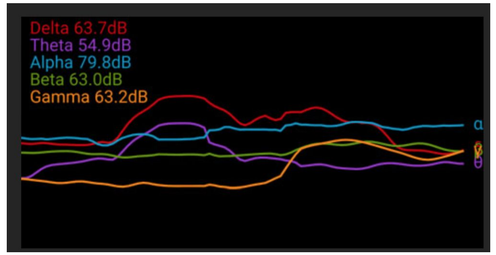
Extract the features and classify the videos. Verified OpenPose, Posenet, and rPPG implementations.

Test the model with new meditators and see the efficacy.

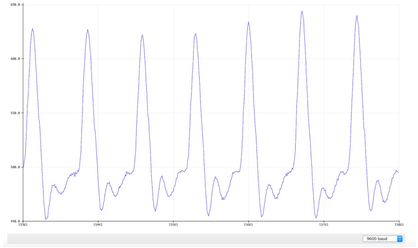
ground truth data

Issue: rPPG not as accurate as we hoped in practice.

Solution: Use a PPG sensor and Muse headset to have some ground truth data. Correlate it with the rPPG and other features. .

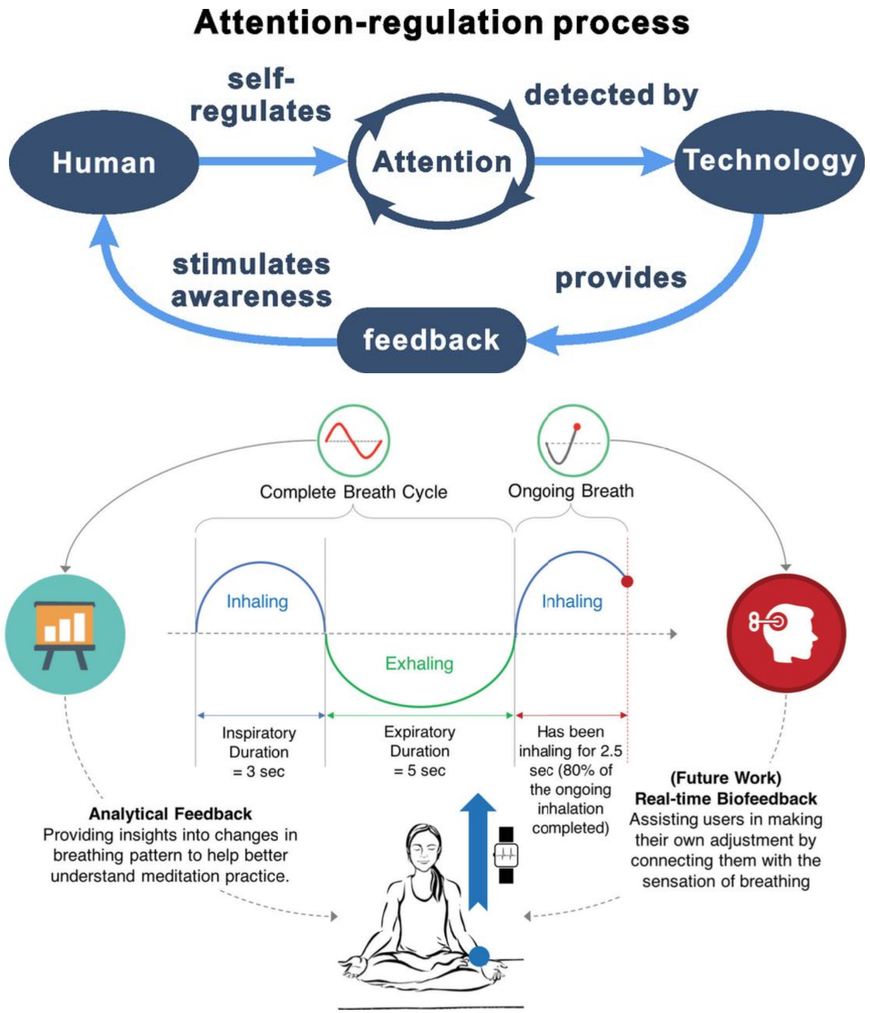


Muse headset and the brainwaves it collects.



Pulse sensor for more accurate PPG data.

13 appendix - other methods

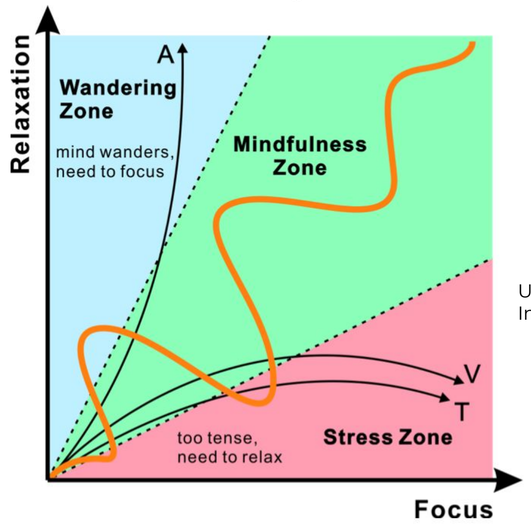


MindfulWatch: A Smartwatch-Based System For Real-Time Respiration Monitoring During Meditation, Hao et al. 2017

TABLE I. TABLE TO SHOW ACCURACY OF TRAINED MODELS

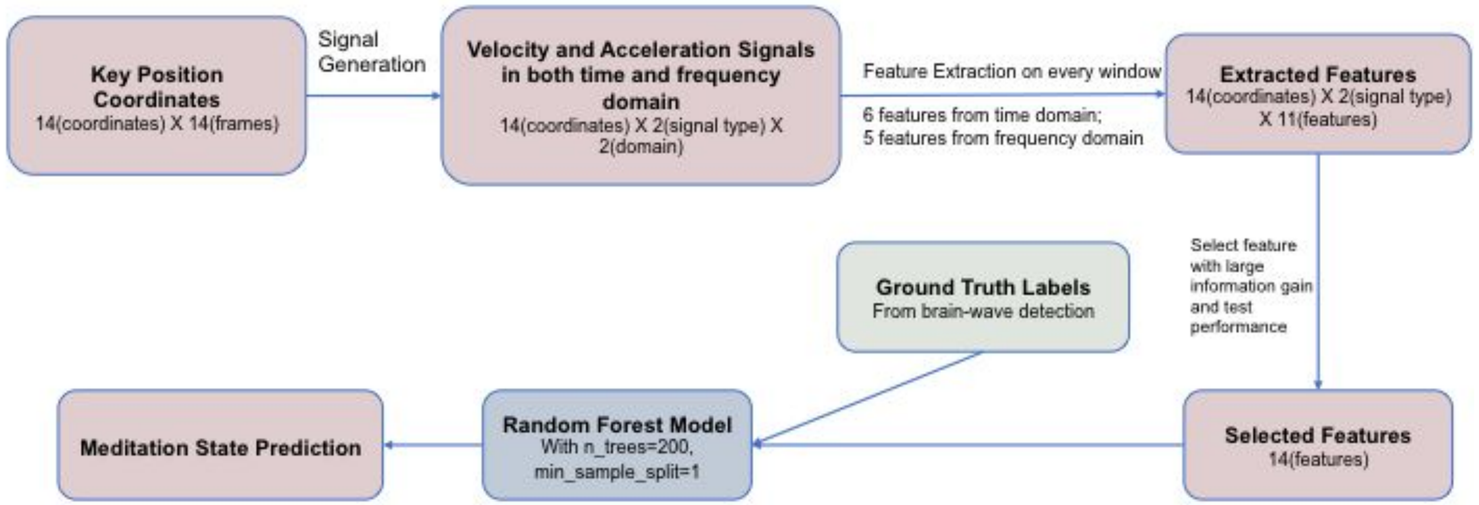
Dataset	Model Accuracy % (2dp)						
	Naive Bayes	*Bayes Net*	*J48*	*Random Tree*	*Random Forest*	*MLP*	*SVM*
OneR	56.21	73.67	80	76.21	**87.16**	74.27	61.18
Information Gain	54.2	71.64	76.85	65.02	78.02	72.22	64.1
Correlation	56.3	72.69	77.05	75.85	84.17	80.82	75.24
Symmetrical Uncertainty	51.49	71.41	76.29	74.35	82.96	72.25	60.1
Evolutionary Algorithm	55.04	70.31	80.65	72.62	85.29	80.85	67.65

A Study on Mental State Classification using EEG-based Brain-Machine Interface (2018)



Understanding the Role of Human Senses in Interactive Meditation, Ahmed et al., 2017

13 appendix - relative alpha



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Maximum Value	√	

Nose velocity				Right eye velocity				Right ear velocity				Right eye acceleration	
Time domain signal		Frequency domain signal		Time domain signal		Frequency domain signal		Time domain signal		Frequency domain signal		Time domain signal	Frequency domain
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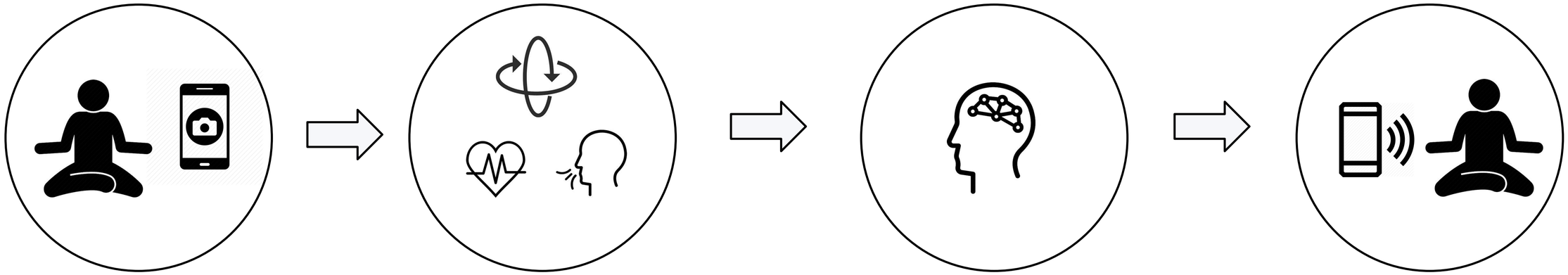

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Real-time Feedback

Give a gentle reminder to the user that they need to focus on their breath

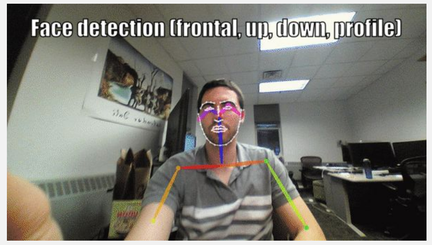
6 implementation - extracting features

There are a number of ways to get signals from the video of a meditator to determine their meditation level.

Heart rate [4], breathing rate [7], and movement can all give a signal to the level of meditation.

Movement

OpenPose - CMU Perceptual Computing Lab [5]



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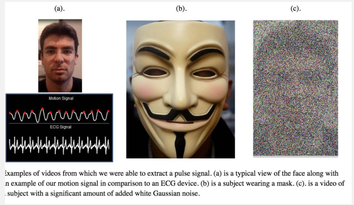

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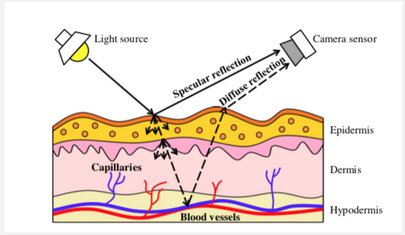

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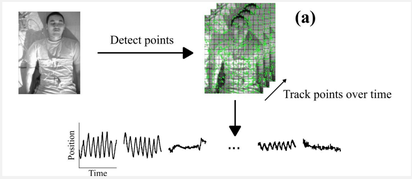

A simple, remote, video based breathing monitor [10]

target and market

Entrepreneurial activities differ substantially depending on the type of organization and creativity involved. Entrepreneurship ranges in scale from solo. Entrepreneurial activities differ substantially depending on the type of organization.

target

entrepreneurial activities differ substantially depending on the type of organization and creativity involved. entrepreneurship ranges in scale from solo. entrepreneurial activities differ substantially depending on the type of organization and creativity involved.

market

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1 background

how many types of meditation are there?

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what meditation will with research focus on?

Research has confirmed a myriad of health benefits associated with the practice of meditation. Physiological benefits include reduced blood pressure, heart rate, lactate, cortisol, and epinephrine; decreased metabolism, breathing pattern, oxygen utilization, and carbon dioxide elimination[1].

01

the act of meditation

The act of meditation is when you notice your mind wandering, and bring your attention back to the object of focus.

02

monkey mind

A common metaphor within the meditation world is that our minds are monkeys, swinging from thought to thought.

creative works

Entrepreneurial activities differ substantially depending on the type of organization and creativity involved. Entrepreneurship ranges in scale from solo. Entrepreneurial activities differ substantially depending on the type of organization.

project title

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2 problem

new meditators are unsure

New practitioners of breath-centric meditation don’t know if they are meditating correctly when they learn it as a new skill.

new meditators’ minds wander

New practitioners’ minds wander more often than experienced meditators

01

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entrepreneurial activities differ substantially depending on the type of organization and

02

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