DES535
Ubiquitous Computing

Dr. Pragma Kar
Assistant Professor
Department of Human-Centered Design

INDRAPRASTHA INSTITUTE *of*
INFORMATION TECHNOLOGY **DELHI**

Google Classroom Code : pcwnf5t

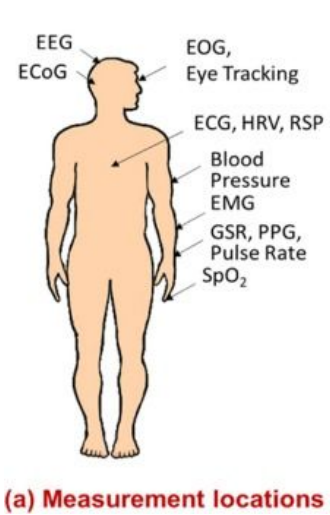
Physiological Sensing

Module VI (Part I)

What are Physiological Signals?

- Physiological signals are the biological processes that occur within the human body and create measurable changes in electrical, mechanical, or chemical activity.

- Some Physiological Signals
  - Electrocardiography (ECG)
  - Electroencephalography (EEG)
  - Electromyography (EMG)
  - Electrooculography (EOG)
  - Photoplethysmography (PPG)
  - Respiratory Signals
  - Blood Oxygen
  - Continuous Glucose Monitoring (CGM)
  - Body Temperature
  - Sweat Analysis



(a) Measurement locations

(b) Collection devices

Image Source: Internet

https://openaccesspub.org/international-physiology-journal/physiological-signals

How to Record Physiological Signals?

Polar H10

Ultrahuman Ring AIR

Empatica Embrace

- Other devices from which physiological parameters can be derived:
  - Smartphones
  - Gaze trackers
  - Smart gloves
  - Smart Masks
  - Smart Shoes
  - Smart Glasses, etc.

Image Source: Internet

What are the Applications of Sensing Physiological Signals?

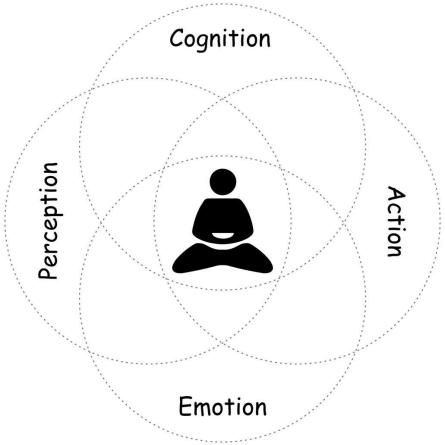


Image Source: Internet

Photoplethysmography (PPG)

- The photoplethysmographic (PPG) signal is defined as oscillations in light transmission through a tissue, which are created by heart beats (Systoles and Diastoles).

- The general interpretation of these oscillations is that they are related to the increase of blood volume in the arteries during systole.

Image Source: Internet

https://www.sciencedirect.com/science/article/abs/pii/B9780128233740000098

Photoplethysmography (PPG) [contd.]

- Optical radiation is used to illuminate peripheral tissue, where it is scattered and absorbed as it travels through different tissue layers before being transmitted through or reflected from the tissue surface.
- This attenuated light intensity is detected by an optical sensor and is recorded as a voltage signal known as the photoplethysmogram (PPG).
- High frequency variations are caused by changes in arterial blood volume with each heartbeat, and lower frequency variations are caused by changes in other tissue components such as venous and capillary blood, bloodless tissue, etc.

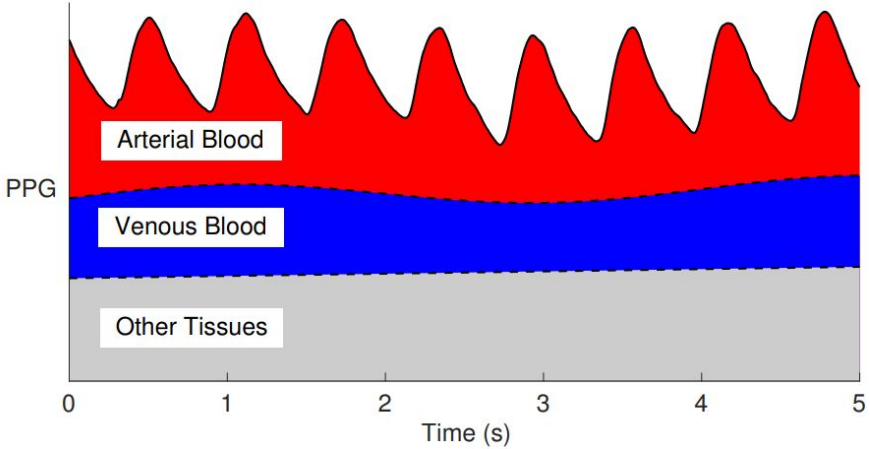


Image Source: Internet

Photoplethysmography (PPG) [contd.]

- Optical radiation is used to illuminate peripheral tissue, where it is scattered and absorbed as it travels through different tissue layers before being transmitted through or reflected from the tissue surface.
- This attenuated light intensity is detected by an optical sensor and is recorded as a voltage signal known as the photoplethysmogram (PPG).
- High frequency variations are caused by changes in arterial blood vol… …h heartbeat, and lower frequen… caused by changes in… components such as venou… …y blood, bloodless tissue, etc.

Why?

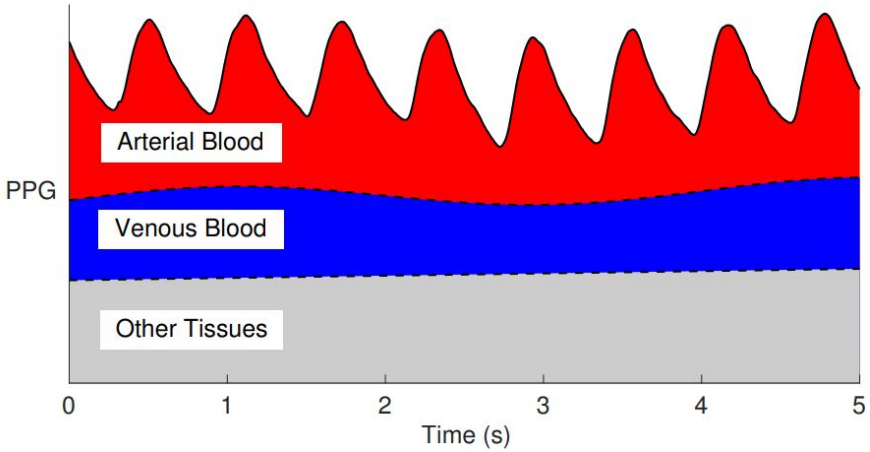
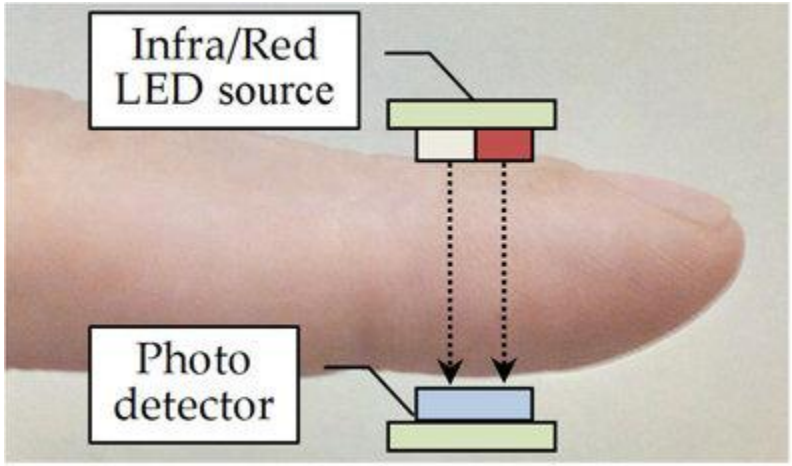


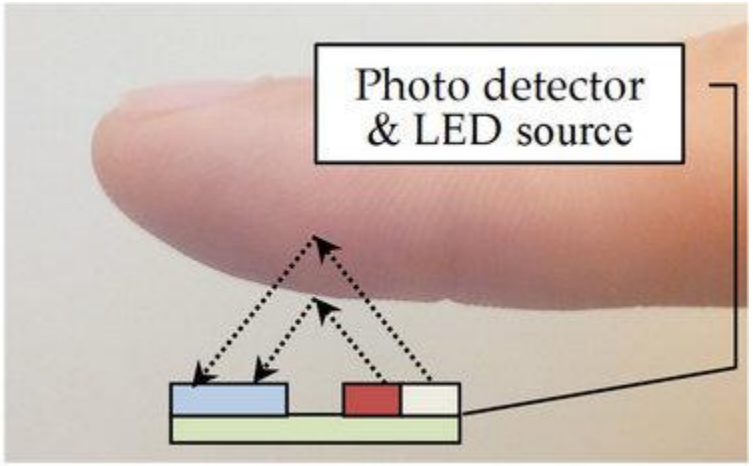
Image Source: Internet

Photoplethysmography (PPG) : Types



Transmission (‘transillumination’) mode

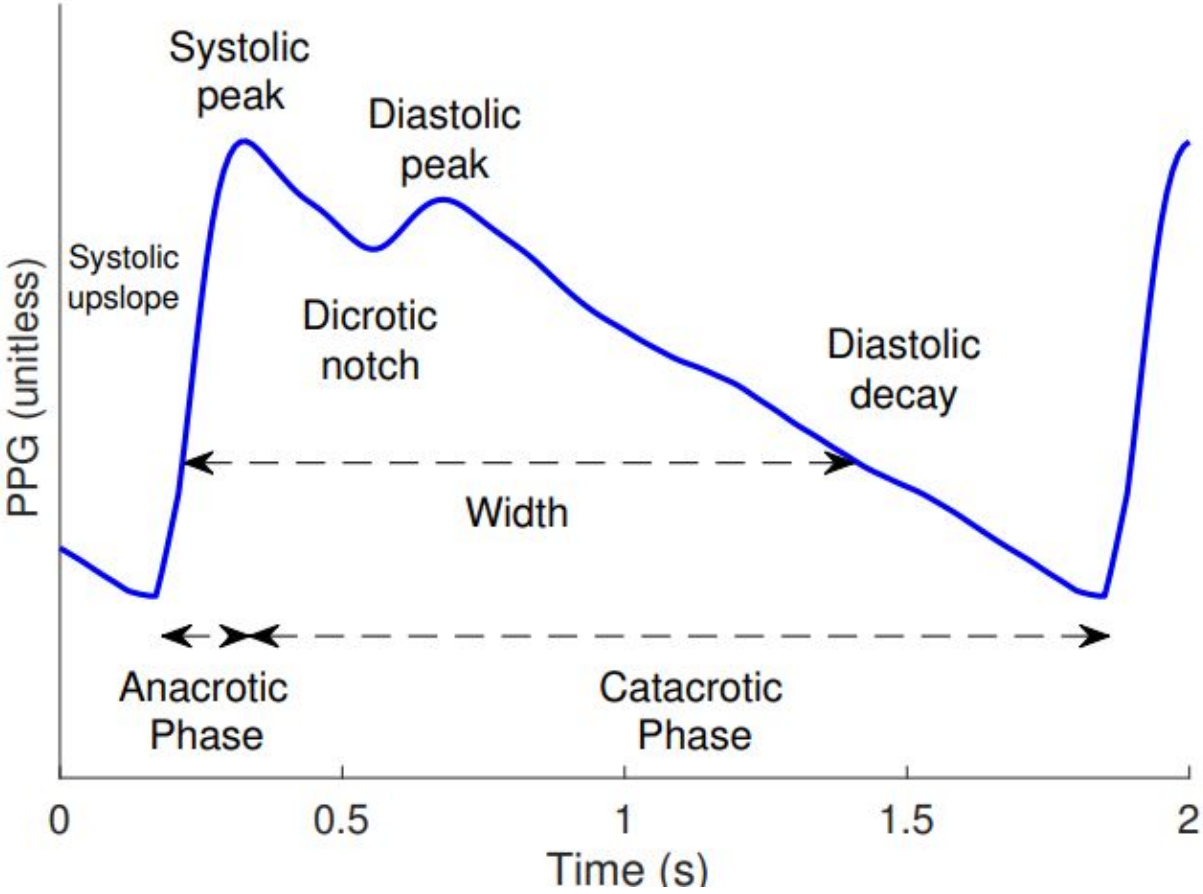
- The LED and photodiode are mounted on opposite sides of a clip, and the light transmitted by the LED passes through the tissue sample to the photodiode.
- Transmission probes are the most widely used probes in healthcare settings, used to measure arterial oxygen saturation.
- Their use is limited to peripheral sites to which a clip can be attached, such as the finger, earlobe, or toe.



Reflection (‘adjacent’) mode

- In reflectance probes, the LED and photodiode are mounted side-by-side, typically millimetres apart, so that the light produced by the LED transilluminates the tissue and the photodiode detects the backscattered light.
- Reflection probes can be used at virtually any vascular tissue site since the LED and photodiode are mounted next to each other, and consequently are widely used in consumer wearables.
- The PPG signal can also be acquired by non-contact methods, i.e., ‘imaging PPG’

Photoplethysmography (PPG) : Arterial Waveform Structure



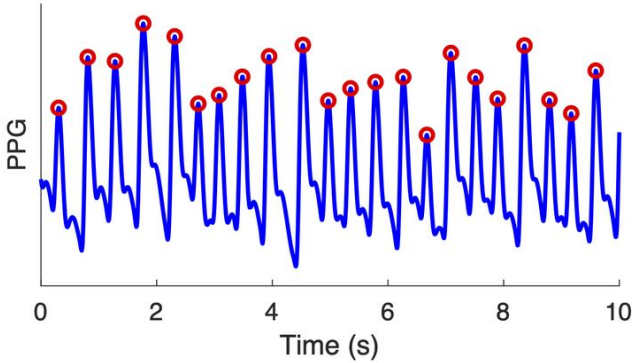
Physiological parameters derived from the waveforms:

- Heart Rate
- Inter-beat-intervals
- Detecting atrial fibrillation
  Atrial fibrillation
- Respiratory rate
- Blood Pressure
- Arterial stiffness
- Others

Common Applications of PPG - Choice of Parameters

How to measure Heart Rate using PPG?

- Location : Wrist
- Mode : Reflectance
- Sampling rate : low (< 40 Hz)
- Wavelength : Short (green/red) to acquire the PPG signal from transcutaneous tissue
- Recording time : Short (≈ 10 seconds)



How to measure Blood Pressure using PPG?

- Location :
- Mode :
- Sampling rate :
- Wavelength :
- Recording time :

What should be the parameters and why?

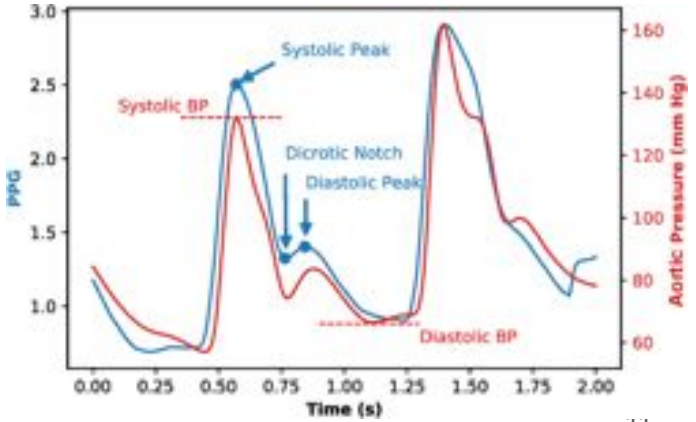
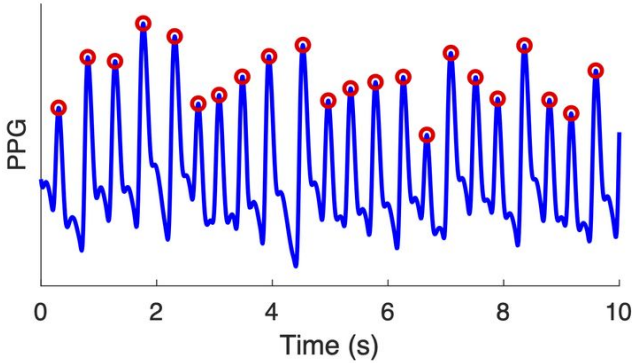


Image Source: Internet

Common Applications of PPG - Choice of Parameters

How to measure Heart Rate using PPG? - Systolic peak detection

- Location : Wrist
- Mode : Reflectance
- Sampling rate : low (< 40 Hz)
- Wavelength : Short (green/red instead of infrared) to acquire the PPG signal from transcutaneous tissue
- Recording time : Short (≈ 10 seconds)



How to measure Blood Pressure using PPG? - Waveform analysis

- Location : Finger
- Mode : Transmission
- Sampling rate : High (> 500 H)
- Wavelength : Long (infrared, λ ≈ 940 nm) to penetrate more deeply and ensure the PPG signal reflects arterial blood volume changes
- Recording time : Long (5-20 mins)

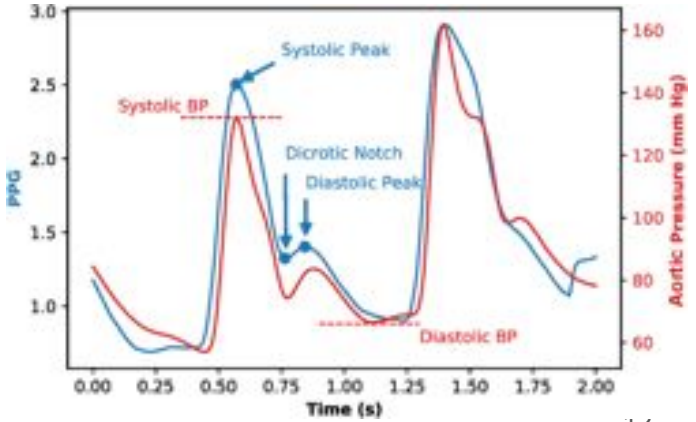
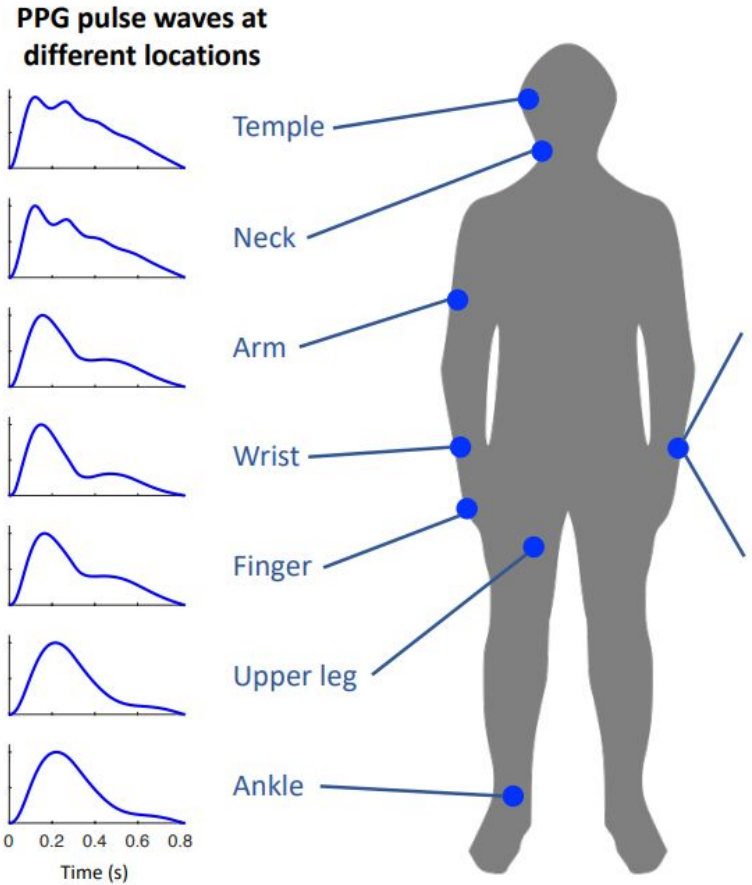
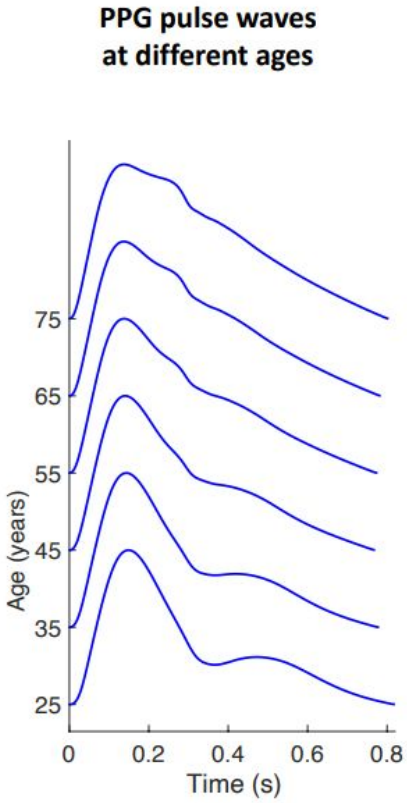


Image Source: Internet

PPG Signals Vs Location Vs Age





Case Study 1

CHI '17: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems

Understanding and Detecting Divided Attention in Mobile MOOC Learning

Xiang Xiao[1, 2], Jingtao Wang[1, 2]

1 Department of Computer Science, 2 Learning, Research and Development Center (LRDC) University of Pittsburgh, Pittsburgh, PA, USA

Problem Statement

- The emergence of mobile apps for Massive Open Online Courses (MOOCs) allows learners to access quality learning materials at low cost and “to control where, what, how and with whom they learn”.
- Unfortunately, when compared with traditional classroom education, learners face more distractions and are more likely to multitask when they study alone in an informal learning environment.
- Can a commodity smartphone detect divided attention?

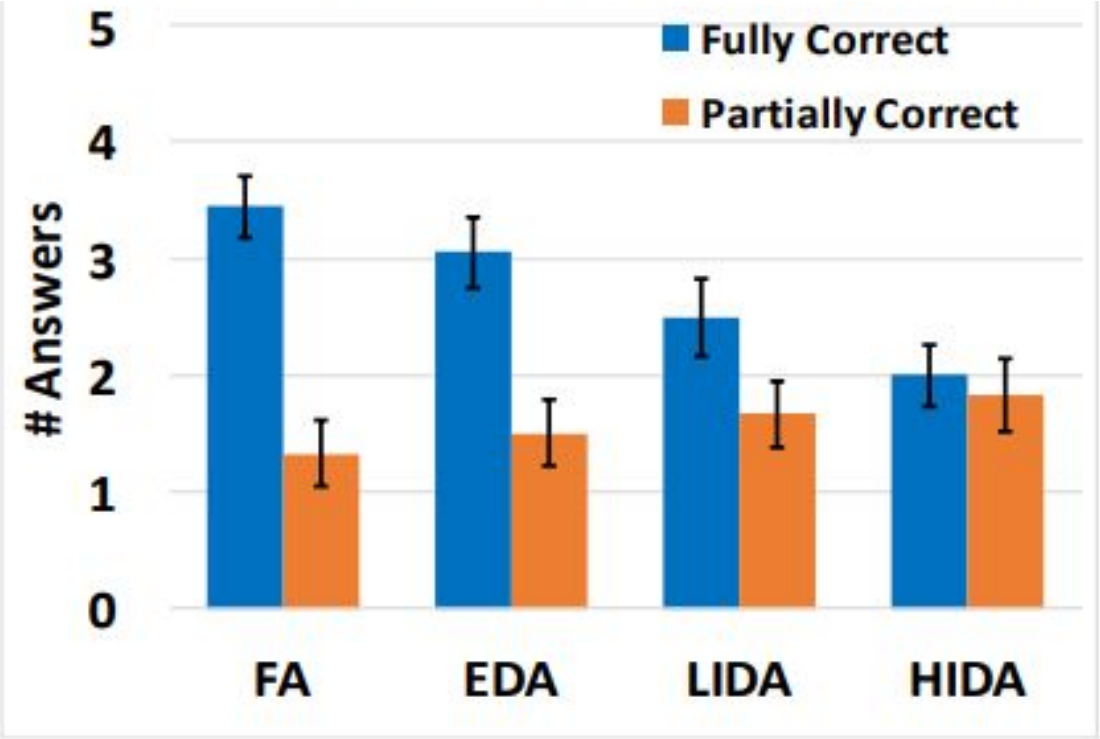
Contribution

- Investigates the impact of divided attention (DA) on the learning process and learning outcomes in the context of mobile MOOC learning.
- Proposes OneMind, a mobile MOOC learning system that detects the presence, type, and intensity of divided attention via implicit physiological signal sensing on unmodified mobile phones.

Proposed Solution

Results

Effect of Divided Attention on Learning Performance



Results

Detecting Divided Attention

Classification Task	Accuracy
FA vs. EDA	72.2%
FA vs. LIDA	75.0%
FA vs. HIDA	83.3%
FA + EDA vs. LIDA + HIDA	83.3%
FA vs. LIDA vs. HIDA	63.0%
FA vs. EDA vs. LIDA vs. HIDA	50.0%

Class Activity : Critical Evaluation

Evaluate the discussed paper on the following aspects, thus mentioning its limitations/advantages:

1. Usability
2. Accuracy
3. Accessibility
4. Ubiquity
5. Scalability and Robustness

For each limitation, suggest a possible improvement.