

# Deep Structures of Collaboration: Physiological Correlates of Collective Intelligence and Group Satisfaction

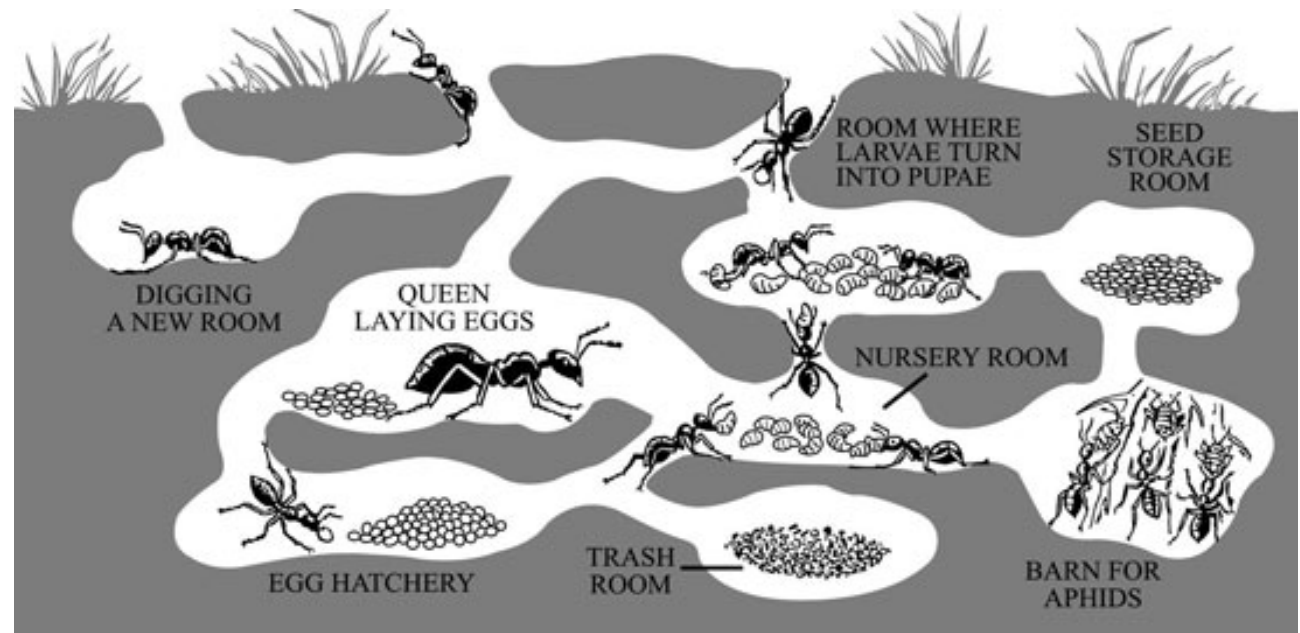
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Anita Williams Woolley, and Laura Dabbish



## Motivation for the Study

In Nature, we often see that collectives are capable of much more than individuals.



## Motivation for the Study

Most human endeavors are collective.







## Motivation for the Study

As it turns out, we can do better!

*Individual brainpower contributes very little to collective smarts.*

*Instead, it's social perceptiveness – the ability to pick up on emotional cues in others – that determines how smart a team is.*

*In fact, social perceptiveness has been found to consistently predict “collective intelligence” in human teams.*

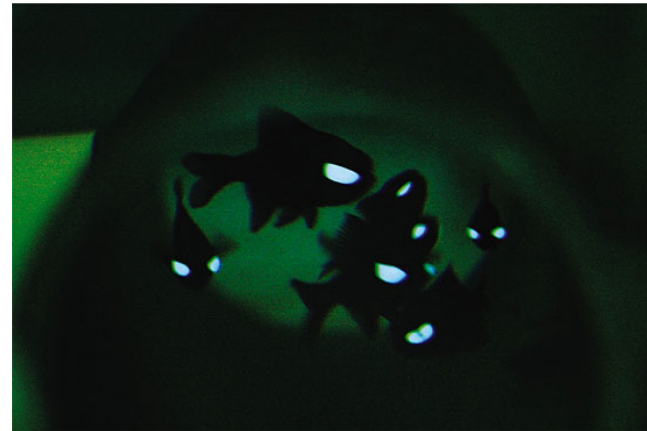
(Woolley et al. 2010)

## Motivation for the Study

“Collective Intelligence” (CI) is groups of individuals acting in ways that seem intelligent.

(Thomas W. Malone, MIT Centre for Collective Intelligence)

We know: collective intelligence manifests in nature through physiological mechanisms.



But, what do we know about the physiological mechanisms of collective intelligence in human teams?

## Motivation for the Study



This is mimicry – it's a physiological mechanism we see in teams all the time!

Physiological - because it is often described as a unconscious spontaneous process.

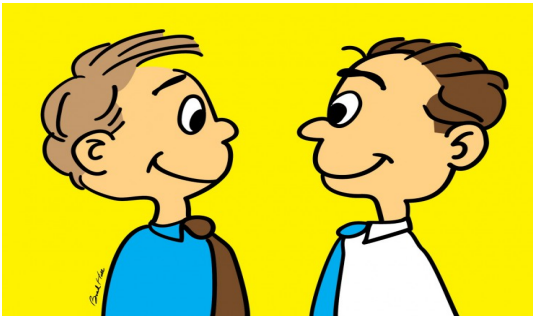
## Previous Work



Synchrony in heart rate

→ Trust

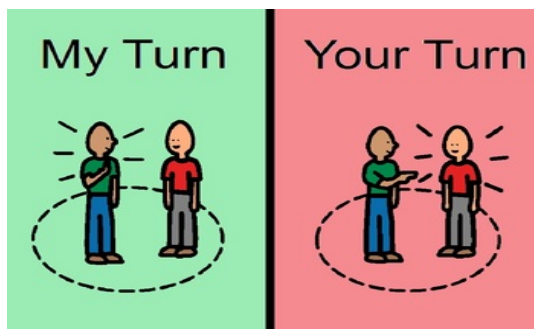
(Mitkidis et al. 2015)



Synchrony of smiles

→ Cohesion

(Mønster et al. 2016)



Distribution in turn-taking

→ Collective Intelligence

(Woolley et al. 2010)

## Problem

The relation between most physiological mechanisms and Collective Intelligence remains unknown.

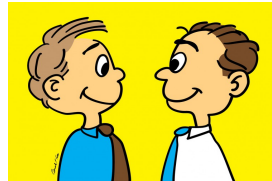
Researchers have found evidence of physiological mechanisms underlying concepts like trust, rapport, and mutual expectations, which may be relevant to CI.

Which is why, in our work, we examine the relationship between a physiological mechanism called synchrony, and CI and group satisfaction, respectively.

*Synchrony is the similarity between people's physiological responses or spontaneous behaviors.*



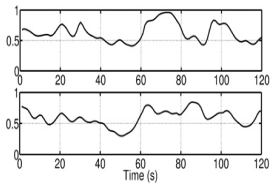
# Key Findings



Synchrony in  
Facial Expressions

$p < 0.05$

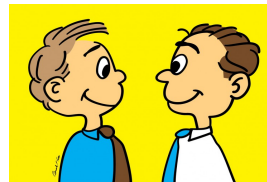
Collective  
Intelligence



Synchrony in Phasic  
Electrodermal Activity

$p < 0.05$

Group  
Satisfaction



Synchrony in  
Facial Expressions

Social  
Perceptiveness

Collective  
Intelligence



## Contributions of the Study

Evidence of new physiological mechanisms underlying Collective Intelligence and Group Satisfaction.

Methods for computationally calculating synchrony in different physiological and behavioral signals.

Creates the potential for several technological interventions in CSCW.

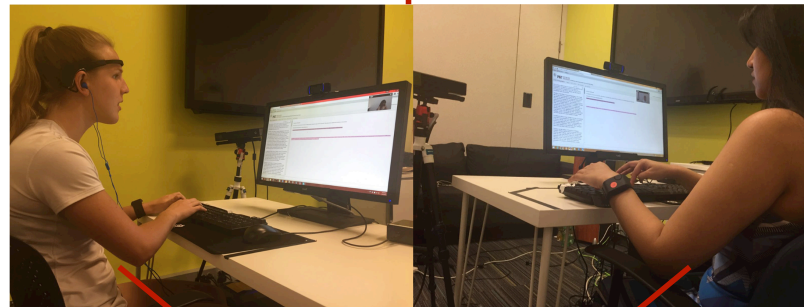
# Our Study

# Our Study

## Social Perceptiveness of the Dyad



Dyads  
collaborating over  
video conferencing



Synchrony in Facial Expressions,  
Electrodermal Activity, and Heart Rate



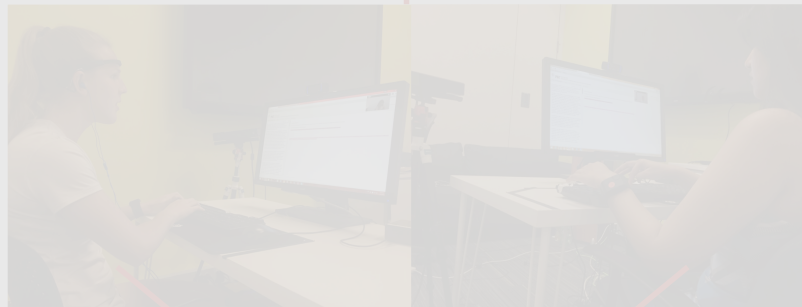
Collective  
Intelligence

Group  
Satisfaction



# Measuring...

## Social Perceptiveness of the Dyad



Synchrony in Facial Expressions,  
Electrodermal Activity, and Heart Rate

Collective  
Intelligence

Group  
Satisfaction

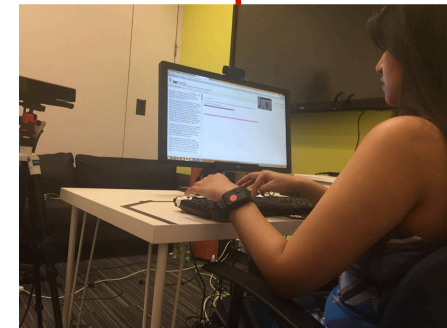
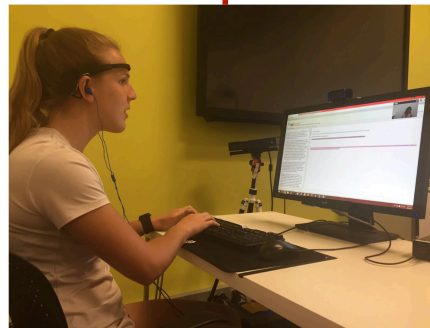




## Social Perceptiveness of the Dyad

*“Social Perceptiveness” is how well a person can understand the emotional cues of other people.*

Social Perceptiveness of the Dyad  $=$  Social Perceptiveness of Person 1  $+$  Social Perceptiveness of Person 2

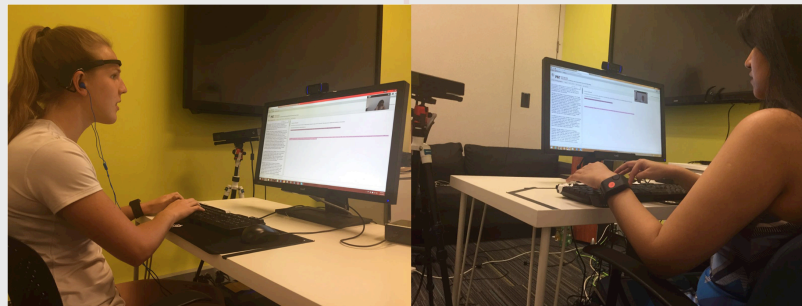
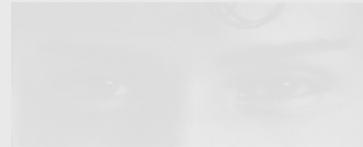


**Playful, Comforting,  
Irritated, or Bored?**

Measured using “Reading-the-Mind-in-the-eyes” Test

# The Tasks

Social Perceptiveness of the Dyad



Synchrony in Facial Expressions,  
Electrodermal Activity, and Heart Rate

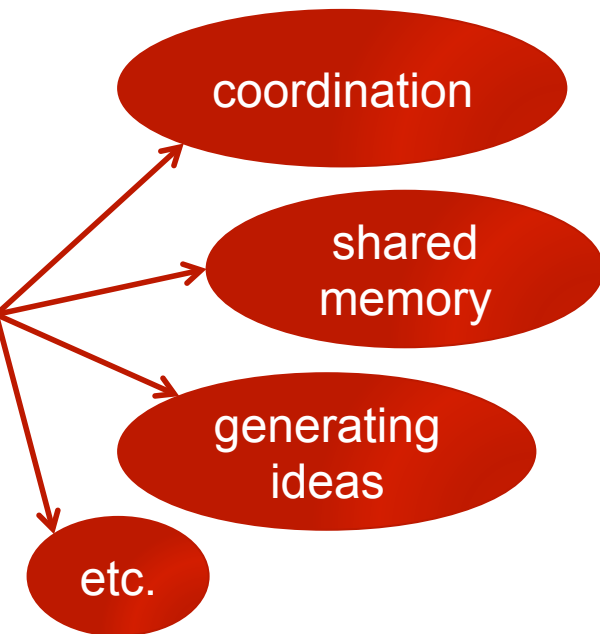
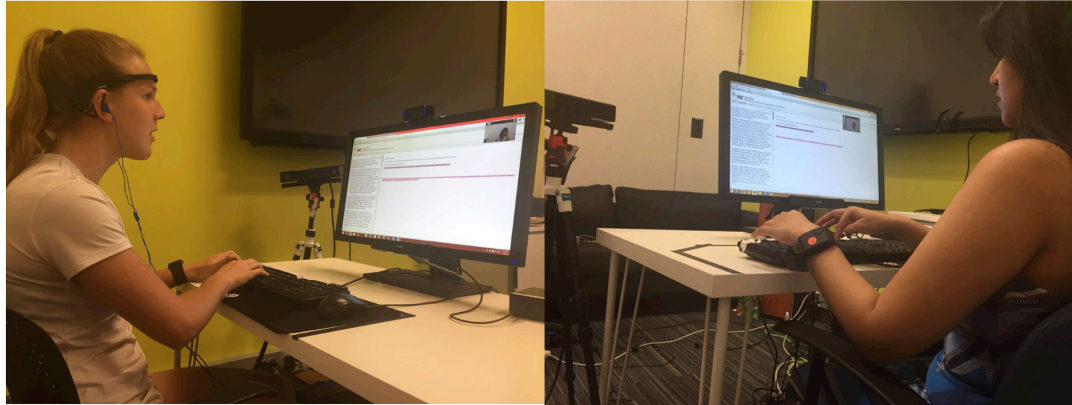


Collective  
Intelligence

Group  
Satisfaction



## The Tasks

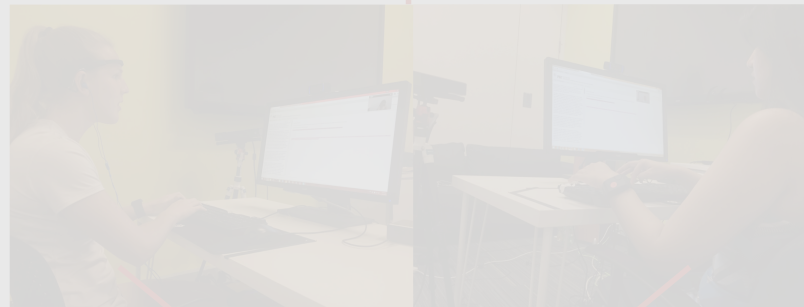
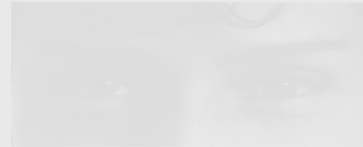


1. Collaborative Typing
2. Matrix (solving logic puzzles)
3. Brainstorming
4. Unscramble the Words
5. Sudoku
6. Memory (answer questions based on your memory about a picture shown)

(Woolley et al. 2010)

# Measuring...

Social Perceptiveness of the Dyad



Synchrony in Facial Expressions,  
Electrodermal Activity, and Heart Rate



**Collective  
Intelligence**

Group  
Satisfaction



# Collective Intelligence

Collective Intelligence = AVERAGING scores on ALL 6 Tasks

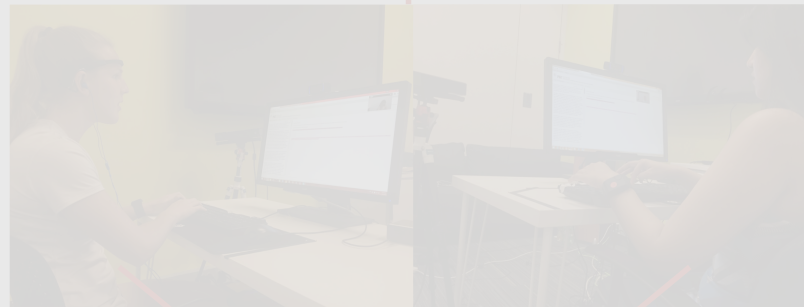
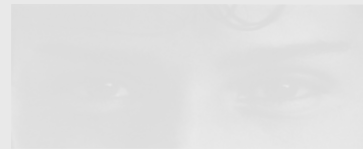
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(Woolley et al. 2010)



# Measuring...

Social Perceptiveness of the Dyad



Synchrony in Facial Expressions,  
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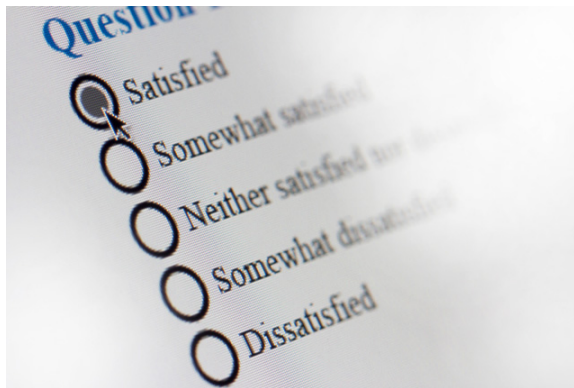
Collective  
Intelligence

**Group  
Satisfaction**



# Group Satisfaction

Group Satisfaction of the Dyad = Group Satisfaction of Person 1 + Group Satisfaction of Person 2



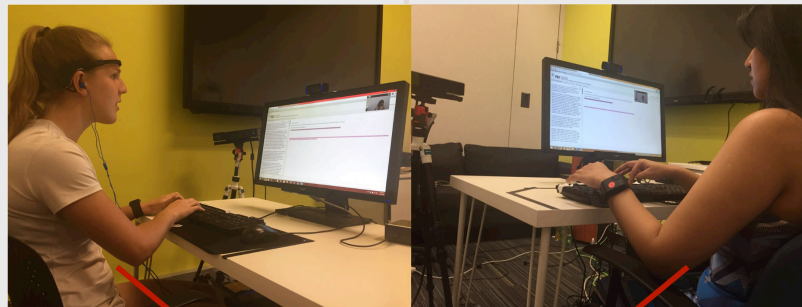
Measured using a Group Satisfaction Survey

Reliability = 0.72

(Wageman et al. 2005)

# Calculating...

Social Perceptiveness of the Dyad



**Synchrony in Facial Expressions,  
Electrodermal Activity, and Heart Rate**



Collective  
Intelligence

Group  
Satisfaction



## Method: Representing Facial Expressions

Why facial expressions?

*Synchrony in facial expressions has been linked to concepts like team cohesion and decision-making, mimicry, rapport or linking and affiliation.*

We compute a representation that encodes both positive and negative facial expressions.

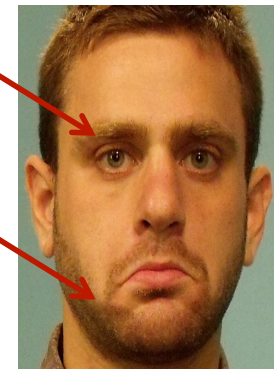


Pulled lip corner

**Positive**

Frown-like eyebrows

Depressed lip corner



**Negative**

# Method: Representing Facial Expressions

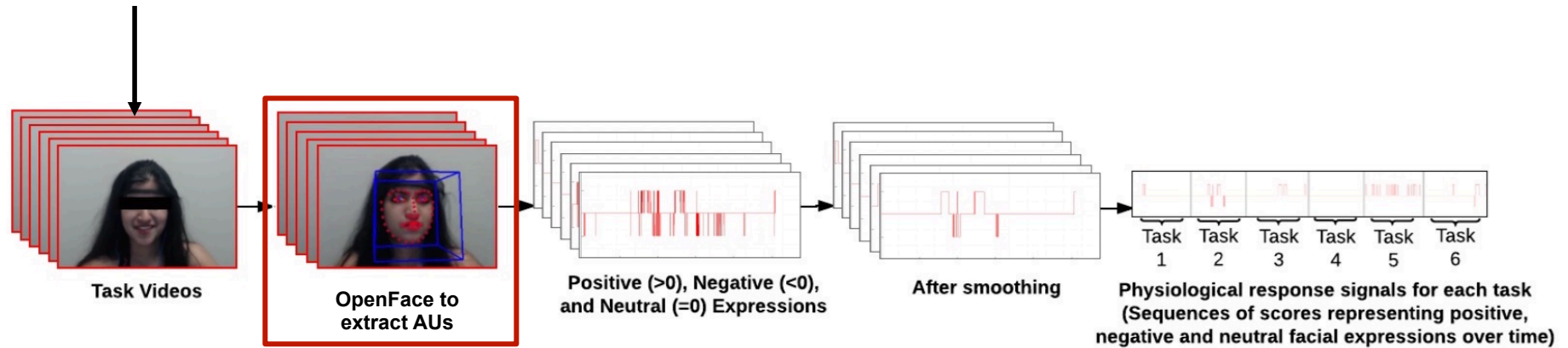
How?



**Sensor:**  
HD Webcam

Facial Action Coding System (FACS):

- Anatomically based
- Describe facial movements in terms of “action units”.



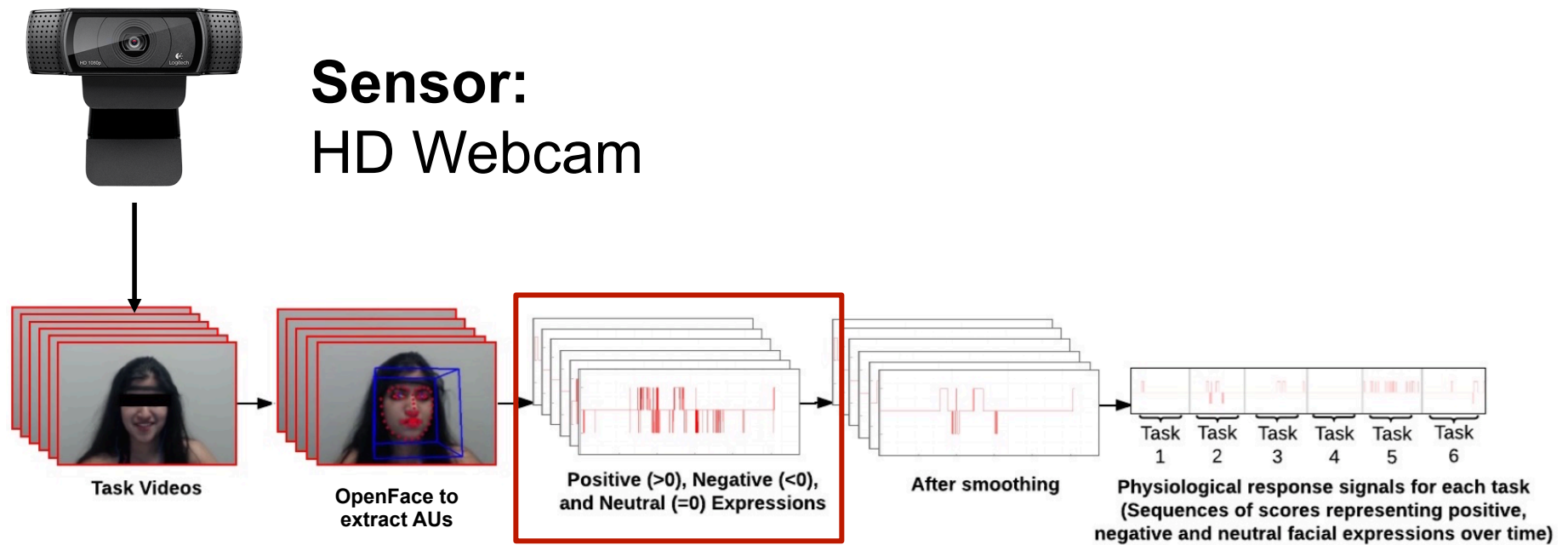
OpenFace software: automatically detects action units in each frame.

(Baltrušaitis et al. 2015)



# Method: Representing Facial Expressions

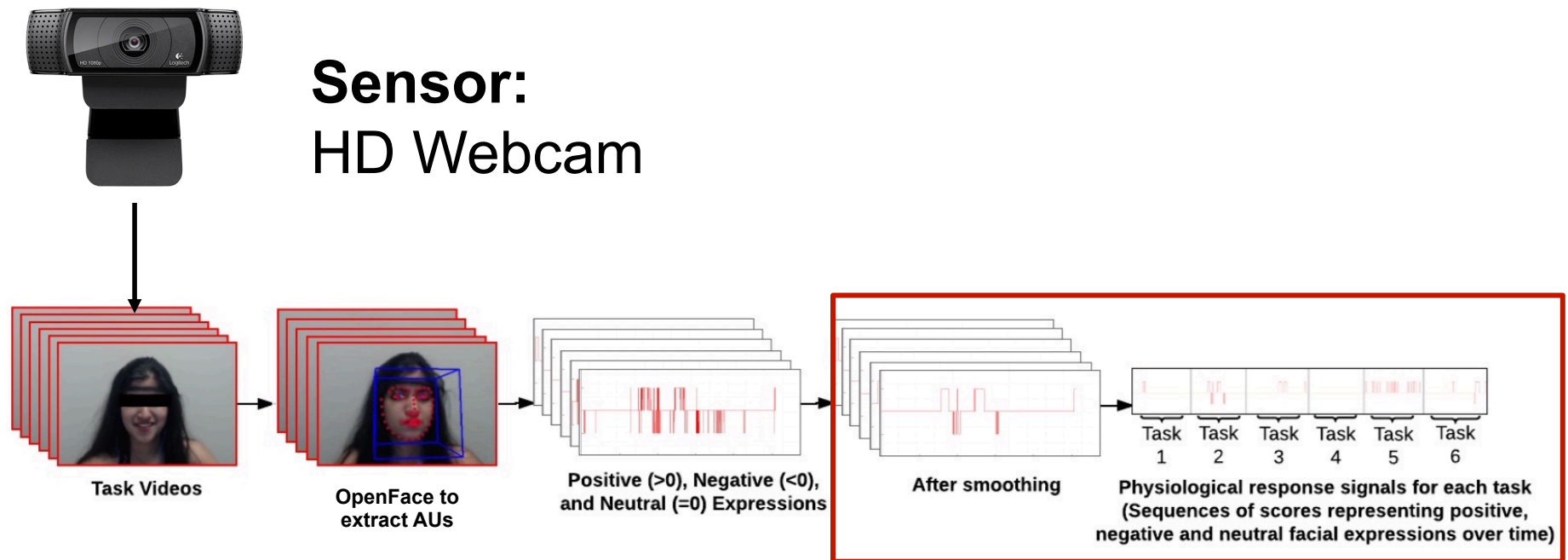
How?



Combinations of action units are classified as positive and negative expressions.

# Method: Representing Facial Expressions

How?



But per-frame detections are noisy, and are hence smoothed.  
Process is repeated for each task.

## Method: Representing Electrodermal Activity

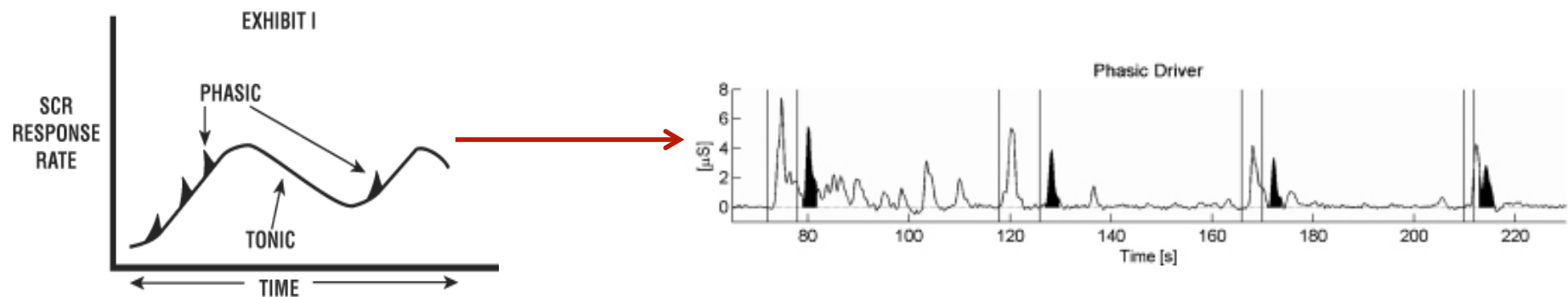
Why electrodermal activity (EDA)?

*Synchrony in electrodermal activity has been linked to concepts favorable for collaboration like engagement and attentiveness, as well as concepts unfavorable for collaboration like anxiety and boredom.*

## Method: Representing Electrodermal Activity (EDA)

It has two components—

- **Tonic:** gradually changes due to changes in the environment, etc.
- **Phasic:** spontaneously changes as response to events.



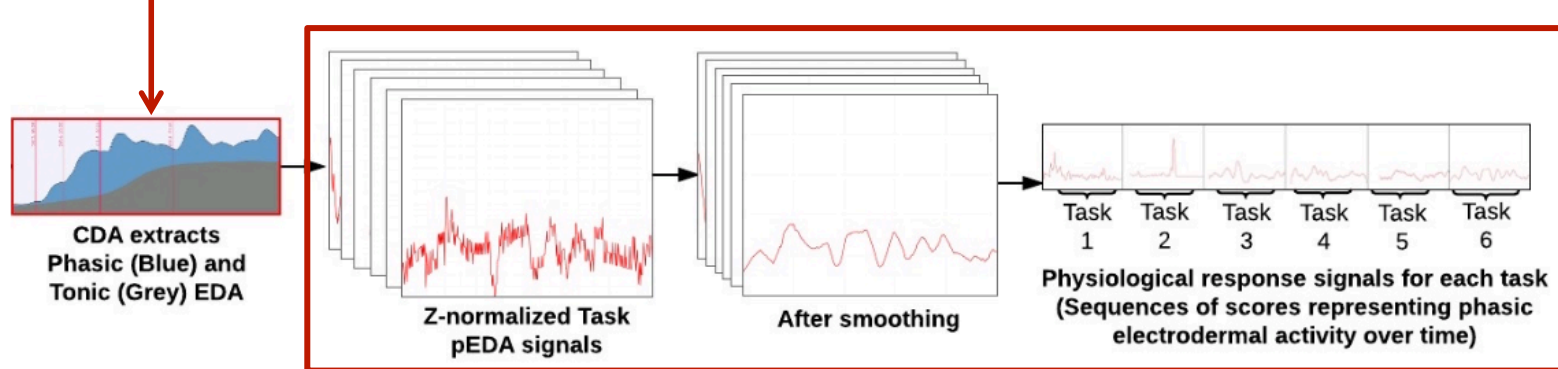
**We extract and analyze the phasic EDA only.**

(Benedek and Kaernbach 2010)

# Method: Representing Electrodermal Activity



**Sensor:**  
Empatica E4 wristband



Phasic EDA is normalized and smoothed.  
Process is repeated for each task.

## Method: Representing Heart Rate

### Why Heart Rate (HR)?

*Synchrony in heart rate has been linked to concepts like trust, and partner's expectations, which might have an effect on collaboration.*

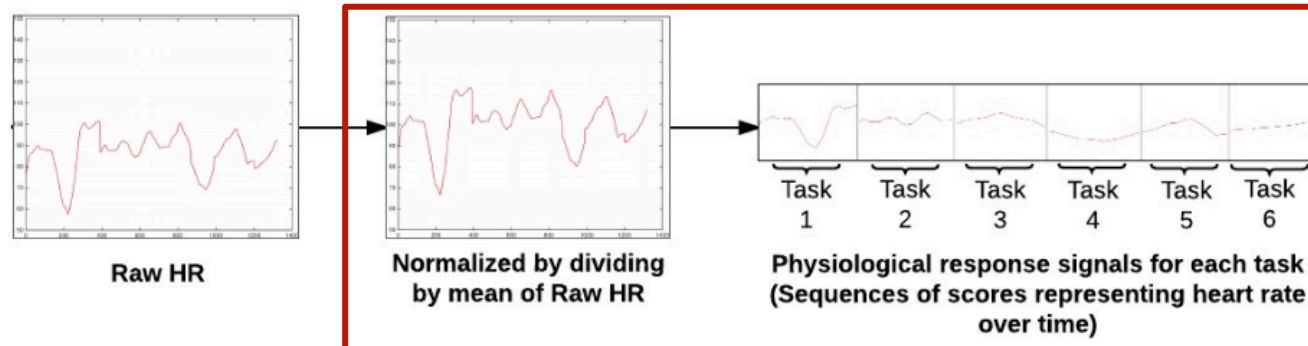
Heart Rate is the average number of heart beats in 60 seconds.



## Method: Representing Heart Rate



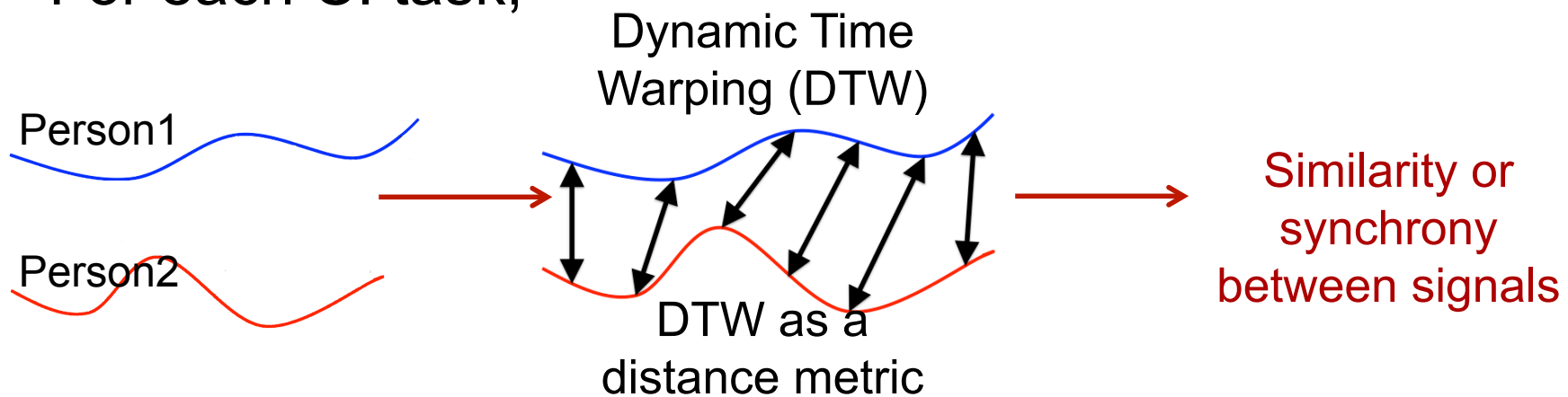
**Sensor:**  
Empatica E4 wristband



Heart rate is normalized to enable inter-subject comparison.  
Process is repeated for each task.

## Method: Computing Synchrony

For each CI task,

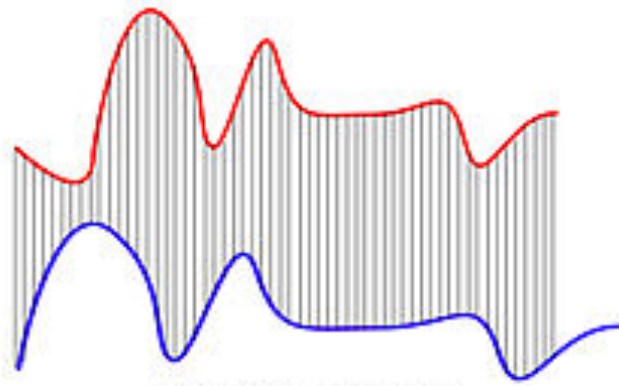


Synchrony of Dyad = AVERAGING synchrony across ALL 6 Tasks

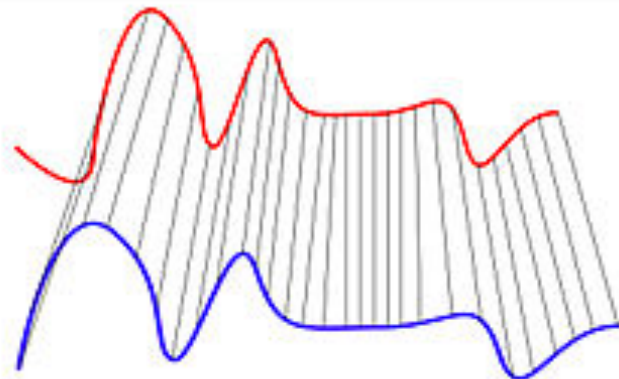
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6. Memory

## Method: Computing Synchrony

### Why Dynamic Time Warping (DTW)?



Euclidean Matching



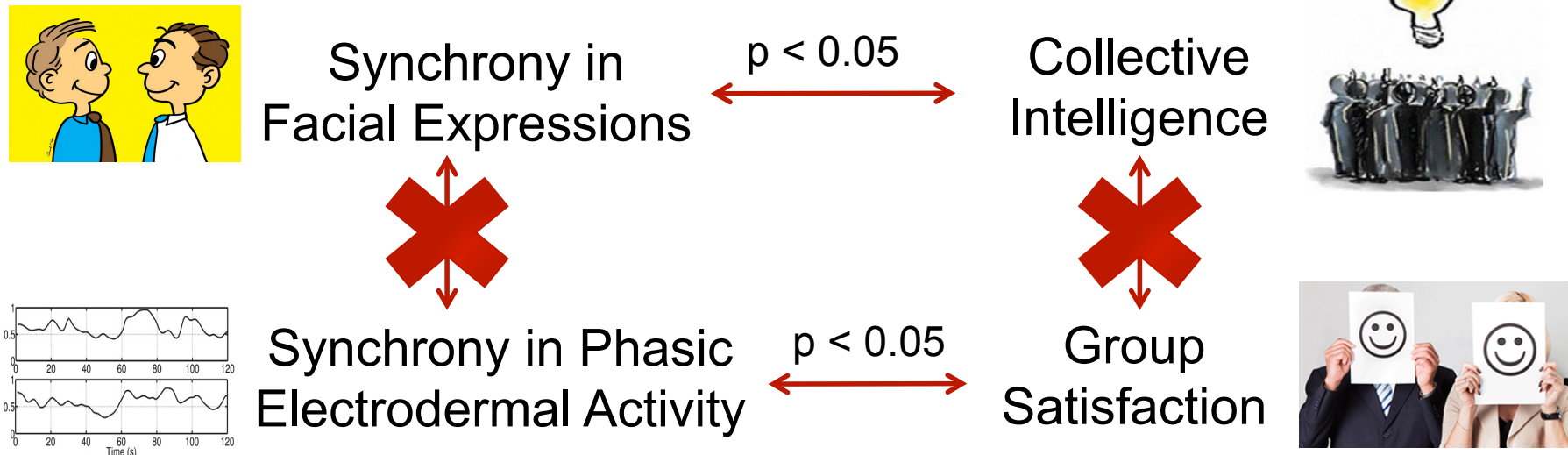
Dynamic Time Warping Matching

Can match

- Lagged responses (e.g., lags in mimicked smiles)
- Responses of varying lengths (e.g., smiles of different durations)

# Results

## Results: Two Separate Paths To Effective Collaboration



- Synchrony in Facial Expressions indicates mutual attention towards social cues → facilitates coordination and performance
- Synchrony in Electrodermal Activity captures shared feelings → effects satisfaction

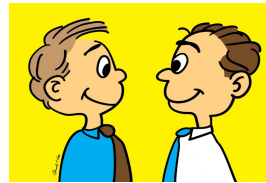
## Results: Social Perceptiveness



Social  
Perceptiveness

$p < 0.01$

Collective  
Intelligence



Synchrony in  
Facial Expressions



Social  
Perceptiveness

Collective  
Intelligence



- Synchrony in Facial Expressions partly explains the relationship between Social Perceptiveness and Collective Intelligence.



## Results: Ethnic Diversity



Ethnic Diversity  $\longleftrightarrow$   $p < 0.05$  **Higher Collective Intelligence**



Ethnic Diversity  $\longleftrightarrow$   $p < 0.05$  **Lower Group Satisfaction**



Ethnically Diverse Dyads  $\longrightarrow$  Who synchronized **more** in their **Phasic EDA**  $\longrightarrow$  **Higher Group Satisfaction**

More results in the paper!

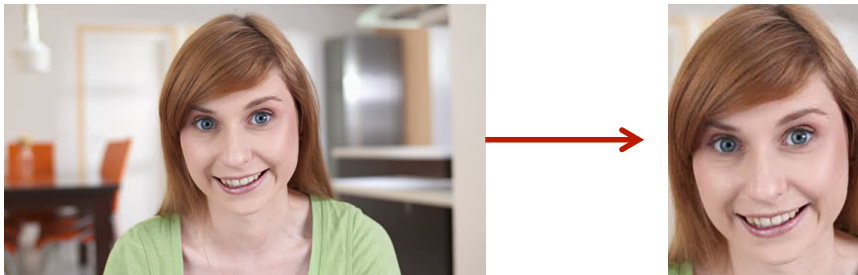
# Implication for CSCW

## Implications for CSCW

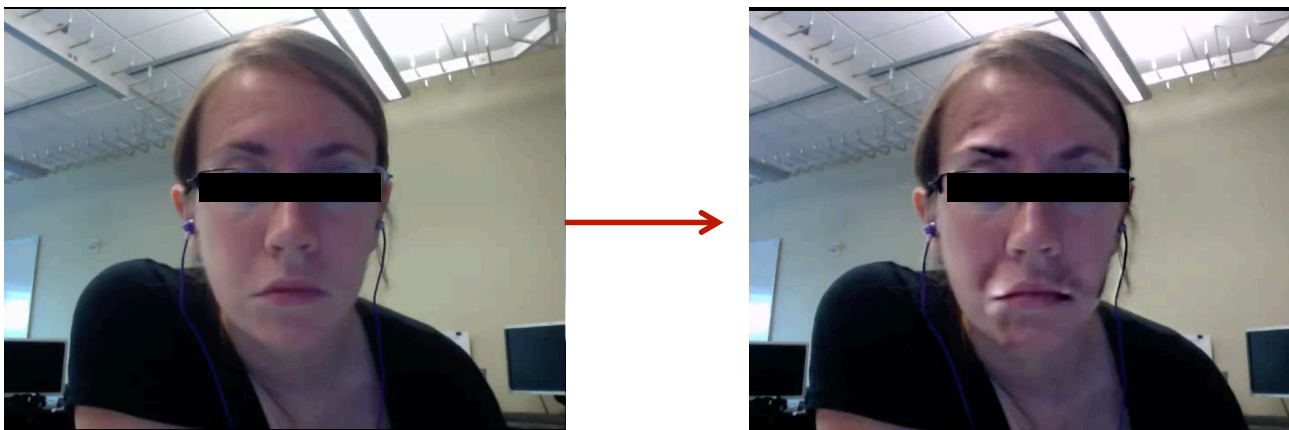
### Indirect Interventions:

Make facial expressions during video calls more salient by,

- Zooming in on the face:



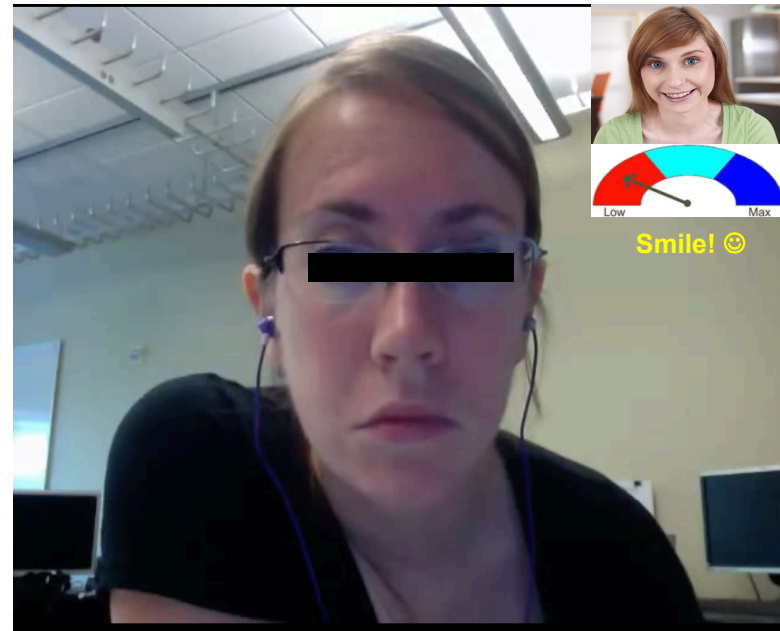
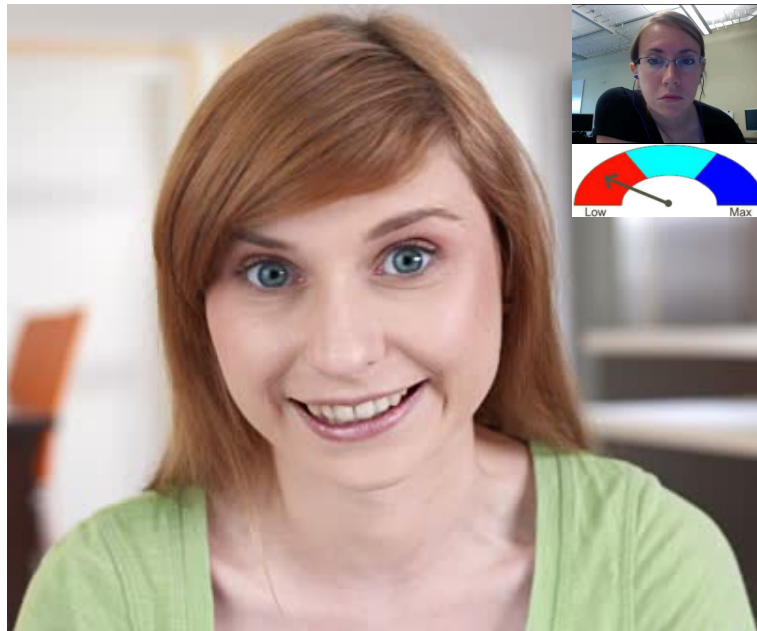
- or amplifying subtle facial expressions:



## Implications for CSCW

### Direct Interventions:

Give users visual feedback on their coordination and collaboration using a “synchronometer”.



Thank you!

- Questions?

- Contact:

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