

VOICE Initiative: Biomedical Research

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Introduction

Project Description: Today, non-verbal children are believed to have minimal intelligence and cognitive abilities. We are aiming to prove this to be false. The Voice Project initiative aims to reverse biases in academia and show that communication is still possible without words or signs. Our current work consists of integrating computer software with biomedical engineering and neurology to explore non-verbal and non-symbolic communication through brain monitoring applications.

Research

Foundational Emotions: Fear, Sadness, Joy/Happiness

1. Heart Rate (HR)

Fear: Heart rate tends to increase with fear due to the activation of the sympathetic nervous system (the fight-or-flight response). The increase in heart rate is part of the body's preparation to face a perceived threat.

- **Range:** 90-120 bpm (can possibly be higher in intense fear situations)

Sadness: Heart rate may decrease in response to sadness. The parasympathetic nervous system (which calms the body) might be more active during this emotional state, leading to slower heart rate and reduced arousal.

- **Range:** 60-80 bpm

Joy: Joy or happiness often leads to an increase in heart rate, though the increase might be less intense than with fear. Positive emotions tend to activate the sympathetic nervous system, but in a more moderate way than fear.

- **Range:** 80-100 bpm

2. Blood Pressure

Fear: Blood pressure typically rises with fear due to the body's stress response. This happens as the body prepares for action—either fight or flight—by sending more blood to muscles and vital organs.

Range: Systolic 120-140 mmHg, Diastolic 80-90 mmHg

Sadness: Blood pressure might either remain steady or slightly decrease with sadness. A prolonged emotional state of sadness can lead to lower overall arousal, including a reduction in blood pressure.

Range: Systolic 100-120 mmHg, Diastolic 60-80 mmHg

Joy: Blood pressure can increase with joy, particularly if the emotional

state is intense or accompanied by physical activity (e.g., laughing or jumping around). However, the increase is typically less pronounced than with fear.

Range: Systolic 110-130 mmHg, Diastolic 70-85 mmHg

3. Skin Conductance (Galvanic Skin Response or GSR)

Fear: Skin conductance (which measures sweating) increases during fear. Fearful emotions trigger the release of adrenaline, which activates sweat glands, leading to higher skin conductance.

Sadness: Skin conductance can decrease during sadness. When experiencing sadness, there's often less physiological arousal and lower sweating.

Joy: Joy may also increase skin conductance, but generally not as much as fear. Positive emotions can lead to mild increases in sweat production, but the response is less intense compared to fear.

4. Respiration Rate

Fear: Breathing rate typically increases with fear. Rapid, shallow breathing is a common response as the body prepares for quick action.

Range: 18-30 breaths per minute

Sadness: Sadness can be associated with slower and deeper breathing, as it is often linked to a more subdued and low-energy state.

Range: 12-18 breaths per minute

Joy: Joy is often marked by faster, shallow breaths, especially if the person is laughing or excited. However, in a calmer state of joy, breathing might be normal or even deeper than usual.

Range: 15-22 breaths per minute

5. Pupil Dilation

Fear: Fear triggers dilation of the pupils (mydriasis). This response is part of the fight-or-flight mechanism, increasing visual sensitivity to detect threats in the environment.

Sadness: Pupil dilation is generally less pronounced with sadness, although there might be some dilation due to emotional distress or fatigue.

Joy: Pupil dilation can occur with joy or excitement, though it is often less noticeable than with fear. Positive emotions can lead to increased alertness, which can cause minor dilation.

6. Facial Expressions

While not strictly physiological markers, facial expressions are closely tied

to emotion and can give additional context to the physiological signals. For example:

Fear: Widened eyes, raised eyebrows, and a mouth that might be open.

Sadness: Downturned lips, furrowed brows, and eyes that might be teary or appear "droopy."

Joy: Smiling, with the mouth forming a wide grin and the eyes potentially squinting or showing "crow's feet."

7. Body Temperature

Fear: Often, body temperature might decrease in response to fear (cold hands or feet), due to the redirection of blood flow to essential organs and muscles.

Sadness: Sadness may lead to a slight decrease in body temperature, especially if it leads to lethargy or feelings of coldness.

Joy: Positive emotions like joy can sometimes cause a slight increase in body temperature, particularly if the joy is linked to physical activity or excitement (e.g., laughing, running around).

8. Cortisol Levels

Fear: Cortisol, the stress hormone, increases during fear as part of the body's preparation for danger.

Range: Approximately 15-25 mcg/dL (can vary widely, depending on the intensity and duration of fear)

Sadness: Cortisol levels may also rise during sadness, particularly if the sadness is prolonged or linked to stress.

Range: Approximately 10-15 mcg/dL (slightly elevated from baseline in some cases)

Joy: Cortisol tends to be lower during positive emotions like joy. Joy and laughter can reduce stress and lower cortisol levels.

Range: Approximately 5-10 mcg/dL (slightly lower than baseline)

9. Muscle Tension

Fear: Increased muscle tension is common with fear, especially in the face, neck, shoulders, and hands. This is related to the fight-or-flight response.

Sadness: Muscle tension tends to decrease with sadness, as the body may feel fatigued or weakened.

Joy: Joy can lead to muscle relaxation and less tension. Laughter and other joyful expressions often involve a relaxation of facial and body muscles.

Ethical Concerns in Data Collection (from those who are unable to give consent)

For individuals who can't provide direct consent, there are a few methods that might help make sure the process is ethical, respectful, all while obtaining effective data collection:

-Proxy Consent: In cases where individuals cannot consent themselves, a legal guardian or family member can provide proxy consent on their behalf. This is often used for vulnerable populations and requires that proxies act in the best interests of the individual.

-Assent Process: Though they may not provide formal consent, nonverbal individuals can sometimes show signs of assent or dissent through nonverbal cues. This might include gestures, eye movements, or physiological signs (e.g., relaxation versus signs of distress). Observing these cues can help determine if they are comfortable participating.

-Institutional Oversight: Working under the guidance of an Institutional Review Board (IRB) or an ethics committee can help ensure that the methods used respect the individual's autonomy and minimize risks. These boards are experienced in overseeing studies involving vulnerable populations.

-Anonymized and Minimal Data: Collecting only essential data and anonymizing it as much as possible can help minimize privacy concerns. Ensuring data security, especially with physiological data, is crucial.

-Continuous Monitoring and Withdrawal: If possible, monitor for signs of distress during the data collection process. This allows the study to be adjusted or paused if signs indicate the participant is uncomfortable.

“ The ethical mandates underlying the conduct of research using human subjects are derived from several sources, including:

- the ancient and traditional duty of physicians to benefit their patients, or at least do them no harm;¹
 - the Kantian philosophical view of human beings as "ends in themselves," never to be used merely as means to ends, or for the advantage of others;²
 - the political and legal concept of autonomy or self-determination that requires consent to any bodily intrusion;³ and
 - the requirements of good scientific method in designing and conducting experiments, including: minimization of risk.⁴ These ethical concepts are often translated into three basic principles that provide a framework for the moral conduct of human subjects research:
- The principle of "autonomy," or personal self-governance, "by adequate un-

derstanding while remaining free from controlling interference by others and from personal limitations that prevent choice” (Faden et al., 1986, p. 8). In order for a research subject to make an autonomous choice, the autonomy of the subject must be respected which includes providing sufficient information for the subject to make an autonomous and informed decision.

- The principle of ”beneficence,” which is concerned with the intent and capacity of science and medicine to avoid harm and provide benefit; in the case of research, this requires careful weighing of potential harms against potential benefits.
- The principle of ”justice,” or treatment according to what is fair, due, or owed, which includes avoiding unfairly burdening subjects or communities of subjects in relation to benefits. ”

Source: National Research Council (US) Committee on Evaluation of 1950s Air Force Human Health Testing in Alaska Using Radioactive Iodine-131. The Arctic Aeromedical Laboratory’s Thyroid Function Study: A Radiological Risk and Ethical Analysis. Washington (DC): National Academies Press (US); 1996. 3, The Ethics of Human Subjects Research. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK232523/>

Codes of ethics and regulations for ethical clinical research include:

- **Nuremberg Code (1947):** It is a set of 10 principles that govern human experimentation:
- Voluntary Consent: the participants in this research have to be voluntary; participants must be fully informed about the nature, duration, and purpose of the experiment.
- Benefit to Society: the experiment’s goal needs to be to produce results that benefit society that cannot be done through other means. Based on Prior Knowledge: the experiment should be grounded in prior animal experimentation and existing scientific knowledge to justify its validity.
- Avoidance of Unnecessary Harm: all unnecessary physical and mental suffering and injury must be avoided.
- No Risk of Death or Disabling Injury: no experiment should be conducted if there is a reason to believe it can cause death or disabling injury, except possibly where the researchers also serve as subjects.
- Risk-Benefit Balance: the risk must not exceed the potential humanitarian importance of the problem the experiment seeks to solve.

- Adequate Preparations: proper preparations and facilities should be available to protect participants from harm.
- Qualified Researchers: only scientifically qualified individuals should conduct experiments.
- Right to Withdraw: participants must have the freedom to withdraw from the experiment at any time.
- Obligation to Terminate: researchers must terminate the experiment if they observe that it is likely to result in harm or injury to the participant.

*** In addition to physiological data, can incorporate other types of inputs to create a more holistic interpretation of an individual's emotional state. (some are the controls of the experiment)**

- Environmental Context: Recording contextual factors like the physical environment, noise level, and who is present can add important context. For instance, loud environments might increase stress responses, while familiar caregivers could have a calming effect. This data could be gathered through passive sensing, such as detecting sound levels or noting the time of day.
- Routine and Activity Patterns: Tracking daily routines, activities, and sleep patterns may reveal emotional cues. For instance, disruptions in sleep or deviations from regular routines might correspond with certain emotional states, like anxiety or discomfort.
- Medical History Data and Trends (sensor aspect @ Jimin): Comparing current physiological and behavioral data with historical data from the same individual can improve accuracy. For example, if the individual shows a particular physiological response consistently during certain activities, it may reveal patterns of enjoyment or distress.
- Sensory Preferences or Sensitivities (sensor aspect @ Jimin): For some individuals, specific sensory inputs—like light, sound, or touch—can affect their emotional state. Tracking the presence of such inputs (e.g., detecting a light level or sound frequency) may help correlate environmental stimuli with emotional responses.

Age, Gender, and Individual Differences in Emotional Physiological Responses

Understanding how physiological responses to emotions vary based on age, gender, and individual differences is crucial for creating systems that can accurately interpret these signals in diverse populations. These factors influence how emotions manifest in the body, requiring careful consideration

when designing devices or algorithms for emotion detection.

Age Differences

Physiological responses to emotions can change significantly across different age groups due to developmental, hormonal, and neurological factors:

Children: Younger individuals often display heightened physiological responses, such as elevated heart rate or respiration rate, to emotional stimuli. This heightened sensitivity is due to the still-developing autonomic nervous system and emotional regulation capabilities. For example, fear may elicit faster heart rate increases and prolonged recovery times in children compared to adults.

Adolescents: Puberty introduces hormonal fluctuations that can amplify emotional reactivity. Increased cortisol levels and more pronounced skin conductance responses are common during this developmental stage.

Adults: In general, physiological responses stabilize as individuals mature. Adults typically exhibit more regulated emotional reactions, with quicker recovery to baseline levels after an emotional event. **Older Adults:** Aging can attenuate physiological responses to emotions. For instance, heart rate variability (HRV) tends to decrease, and responses to stimuli like fear or joy may be less pronounced compared to younger individuals. However, older adults often show greater emotional resilience and a stronger tendency to focus on positive experiences.

Gender Differences

Gender influences emotional expression and physiological responses due to biological, cultural, and social factors:

Heart Rate and Blood Pressure: Studies suggest that men and women may exhibit different heart rate and blood pressure responses to emotional stimuli. For instance, women often show greater increases in heart rate and skin conductance during emotionally charged events, potentially linked to higher sympathetic nervous system activation.

Cortisol Levels: Women may experience stronger cortisol responses to stress or fear due to hormonal variations, particularly during certain phases of the menstrual cycle.

Emotional Processing: Cultural and societal norms often encourage women to express emotions more openly, which may influence observable physiological responses. Men, on the other hand, might suppress emotional reactions, leading to less overt physiological changes despite internal emotional arousal.

Individual Differences Beyond age and gender, individual differences such as personality traits, health conditions, and baseline physiological variability play a significant role in emotional responses:

Personality Traits: Individuals high in traits like neuroticism may show heightened physiological responses, such as increased heart rate or cortisol release, to stress or fear. Conversely, those with high levels of emotional stability may exhibit more muted responses.

Health Conditions: Factors such as cardiovascular health, respiratory conditions, or neurological disorders can alter physiological responses to emotions. For example, individuals with hypertension may show exaggerated blood pressure responses to stress, while those with anxiety disorders might experience heightened heart rate and skin conductance levels even at rest.

Baseline Variability: Some individuals naturally have higher or lower baseline metrics for physiological markers like heart rate or skin conductance. These baselines must be considered to accurately interpret changes due to emotional states.

Considerations for Emotion Detection Systems

- Algorithms and devices must account for these variations to avoid biases or inaccuracies. For instance, age- and gender-specific thresholds can be incorporated when interpreting physiological data.

- Baseline measurements should be individualized to each user to account for personal physiological norms and ensure accurate emotion detection.

- Devices must be adaptable and capable of learning from user data over time, refining interpretations based on observed patterns specific to the individual.

Muscle Tension and Emotional States

Muscle tension is a key physiological indicator of emotional states, reflecting the body's preparation for action or relaxation in response to stimuli. Variations in muscle tension are closely tied to the autonomic nervous system's activity, influenced by emotional arousal and the specific emotion experienced. This connection provides valuable insights for developing systems that interpret physiological data to infer emotions, particularly for individuals unable to communicate verbally.

Fear and Muscle Tension

-Fear is characterized by a significant increase in muscle tension, especially in areas like the face, neck, shoulders, and hands. This heightened tension stems from the activation of the sympathetic nervous system as part of the fight-or-flight response. The body prepares for immediate action, whether to confront a threat or escape from it.

Observable Effects: Clenched fists, stiffened posture, and tighten facial muscles (e.g., furrowed brows, wide eyes).

Significance: Monitoring muscle tension can help identify fear in non-verbal individuals, enabling caregivers or devices to detect distress.

Sadness and Muscle Tension

-Sadness often leads to a decrease in muscle tension, as this emotion is typically associated with reduced arousal and energy levels. The body may feel weaker or fatigued, reflecting the emotional state.

Observable Effects: Slumped posture, relaxed or drooping facial muscles, and less movement overall.

Significance: Detecting low muscle tension alongside other markers can indicate sadness or emotional withdrawal, guiding caregivers to provide comfort or support.

Joy and Muscle Tension

Joy or happiness is often accompanied by moderate muscle relaxation, although specific joyful expressions may involve increased activity in certain muscles. For instance, smiling activates facial muscles, while laughter engages the diaphragm and other muscle groups.

Observable Effects: Relaxed shoulders, natural smiles, and spontaneous movements such as clapping or jumping.

Significance: Increased muscle activity in a relaxed context can signal positive emotions, which is crucial for understanding moments of joy in non-verbal individuals.

Applications in Non-Verbal Communication

-By incorporating sensors capable of detecting muscle tension (e.g., electromyography or wearable sensors) into a broader emotional monitoring system, caregivers and clinicians can: Recognize distress or discomfort (e.g., fear or sadness).

-Identify moments of happiness and relaxation.

-Gain a better understanding of emotional states without requiring verbal feedback.

This data can be integrated with other physiological markers like heart rate, skin conductance, and pupil dilation to create a holistic interpretation of emotions, enabling devices to communicate an individual's needs or feelings effectively.

Technical Challenges and Solutions in Emotion Detection Devices

Developing a device to translate physiological data into emotions presents several technical challenges that require innovative solutions. These challenges stem from the complexity of accurately capturing, processing, and interpreting physiological signals, particularly for non-verbal individuals whose emotional states may not align with typical baselines.

1. Data Noise and Signal Interference

One of the primary issues in physiological monitoring is the **presence of noise in the data**. For instance, motion artifacts can distort heart rate or skin conductance readings, especially in wearable devices. Environmental factors like temperature, humidity, or electromagnetic interference can further compromise signal quality.

Solution: Advanced signal processing techniques, such as adaptive filtering and machine learning-based noise reduction, can help isolate relevant physiological markers. Additionally, multi-sensor arrays that cross-validate data across modalities (e.g., combining heart rate and skin conductance) can enhance reliability.

2. Individual Variability

Physiological responses to emotions are highly individualized, **influenced by factors such as age, gender, health conditions, and baseline emotional states**. For example, what indicates stress in one person might signify excitement in another.

Solution: Personalized calibration protocols can be implemented during the initial setup of the device. These protocols involve collecting baseline data under various controlled emotional states to establish individualized benchmarks. Machine learning models trained on diverse datasets can also generalize better across populations while adapting to individual nuances.

3. Real-Time Data Processing

Emotion detection requires rapid analysis of large volumes of physiological data to provide real-time feedback. However, this poses computational

challenges, particularly in resource-constrained environments like portable or wearable devices.

Solution: Edge computing, where data is processed locally on the device instead of being transmitted to a remote server, can reduce latency and improve efficiency. Leveraging optimized algorithms, such as lightweight neural networks, ensures that the device remains responsive without sacrificing accuracy.

4. Sensor Design and Placement

Ensuring accurate data collection often depends on the design and placement of sensors. Poorly placed sensors may fail to capture relevant signals, while uncomfortable designs may discourage consistent usage.

Solution: Innovative sensor designs, such as flexible and stretchable electronics, can improve comfort and adaptability. Strategic placement of sensors, informed by human anatomy, can enhance signal quality. For instance, wrist-mounted devices for pulse and skin conductance, or headbands for EEG readings, can be effective without being intrusive.

5. Interpreting Complex Emotional States

Physiological markers often overlap for different emotions, making it challenging to distinguish between states like stress and excitement, or sadness and fatigue.

Solution: Combining multiple physiological signals—such as heart rate variability, galvanic skin response, and temperature—can help disambiguate overlapping emotions. Additionally, integrating contextual data, such as time of day or user activity, can provide a richer understanding of emotional states.

By addressing these challenges with targeted solutions, emotion detection devices can become more reliable, adaptable, and accessible, bringing us closer to empowering non-verbal individuals and enhancing emotional understanding across various contexts.

Literature Reviews on Correlation Between Biological Vitals and Emotions

Title: The pupil as a measure of emotional arousal and autonomic activation

Author(s): Margaret M. Bradley, Laura Miccoli, Miguel A. Escrig, Peter

J. Lang

Summary of Source: Hess and Polt (1960) observed that pupil dilation and constriction were influenced by emotional stimuli, but their findings lacked replicability due to methodological limitations, such as small sample sizes and absence of statistical analysis. Libby et al. (1973) expanded this research by using more participants and stimuli, finding that "attention-getting" images increased pupil dilation, though results were mixed regarding emotional valence. Recent studies suggest that emotional arousal, not valence, drives pupil dilation, with Steinhauer et al. (1983) and Aboyoun and Dabbs (1998) reporting that arousing stimuli increase pupil size regardless of hedonic content. The current study revisits these findings using a modern eye-tracking system and standardized IAPS images. It also examines the autonomic nervous system's role, distinguishing between sympathetic and parasympathetic influences on pupil changes. Results showed that emotional images, whether pleasant or unpleasant, elicited greater pupil dilation and skin conductance compared to neutral images, while heart rate deceleration was linked to unpleasant stimuli. Luminance effects were controlled to isolate emotional arousal as the primary driver of pupil changes, reinforcing the hypothesis that arousal, rather than valence, modulates these responses. These findings contrast earlier research by Hess and Polt and partially align with Libby et al.'s work, emphasizing the complexity of emotion-driven physiological changes.

Significance: The findings on pupil dilation and its correlation with emotional arousal provide valuable insights for my project, which aims to translate physiological data into emotions to help non-verbal individuals communicate. Knowing that pupil size reflects arousal regardless of whether the emotion is positive or negative simplifies the challenge of emotion detection. Coupled with evidence that heart rate and skin conductance are reliable markers of emotional intensity, I can refine the data streams my device will analyze. Additionally, understanding that arousal often outweighs valence in emotional responses helps me focus on detecting "how much" emotion is present rather than attempting to classify it. This research gives me confidence in designing a system that prioritizes clarity and precision, making meaningful communication possible for those who can't express themselves verbally.

Title: The influence of happiness, anger, and anxiety on the blood pressure of borderline intensives

Authors: James, G D; Yee, L S; Harshfield, G A; Blank, S G; Pickering, T G

Summary of Source: This study investigates how emotions like happiness, anger, and anxiety influence blood pressure in 90 individuals with borderline hypertension during 24-hour monitoring. Participants recorded their emotional states (happiness, anger, or anxiety) alongside 1152 ambulatory blood pressure readings. Data analysis revealed that emotional arousal significantly increased systolic and diastolic blood pressure, independent of position or location. Notably, anger and anxiety were associated with higher blood pressure than happiness. Happiness was inversely correlated with systolic pressure, while anxiety was positively linked to diastolic pressure. The extent of emotional impact varied with individuals' daily blood pressure variability, suggesting that more labile blood pressure amplifies emotional effects.

Significance: This study directly supports your project's aim to use physiological signals, such as blood pressure, to infer emotional states for non-verbal communication. It demonstrates that distinct emotions are associated with specific, measurable changes in blood pressure, providing a foundation for developing algorithms to map physiological data to emotional states. Additionally, the findings emphasize the importance of accounting for individual variability, which could guide the personalization of your device for more accurate emotional translation. This research validates the feasibility of leveraging blood pressure as a meaningful biomarker in your communication device.

Research Plan (Idea for the Biomedical Team):

Objective: To test whether physiological metrics (e.g., heart rate and blood pressure) can be mapped to emotional states and used as a foundation for creating a device that helps non-verbal individuals communicate emotions.

Materials: A heart rate monitor and a blood pressure cuff. A computer with data acquisition software (e.g., Arduino, MATLAB, or Python). Emotionally stimulating materials (e.g., images, videos, or sounds validated to induce specific emotions such as happiness, sadness, or anger). Participants who can provide feedback about their emotional state.

Procedure: Baseline Measurement: Have participants sit in a calm environment. Record their resting heart rate and blood pressure for a baseline. Stimuli Presentation: Present participants with stimuli designed to evoke a range of emotions (e.g., a happy video clip, a sad piece of music, etc.). Allow time between stimuli to return to baseline.

Data Collection: Measure heart rate and blood pressure continuously dur-

ing each stimulus presentation. Record the participant's self-reported emotional state after each stimulus for correlation.

Data Analysis: Analyze trends in heart rate and blood pressure for each reported emotion. Identify patterns (e.g., increased heart rate for excitement or sadness). Prototype Testing (Optional): Use the identified patterns to design a simple algorithm that assigns a specific emotional "label" based on the physiological data collected. Test if the algorithm's labels match self-reported emotions

Hypothesis: There will be measurable, consistent changes in heart rate and blood pressure associated with specific emotional states, forming the basis for translating physiological signals into emotional communication.