Topics (min 1)

i2. Human-AI collaboration in art
d1. The creative process
d2. Human - centered design
a1. Emotion, Perception, Experience

Navigating Emotions: A Multimodal Approach to Redefining Nautical Naval Design

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Abstract

This study outlines an innovative approach to nautical naval design, merging artificial intelligence with the nuanced analysis of human emotions to elevate the sea travel experience.
A collaboration between the University of Genoa's Ph.D. program in Marine Science and Technology and the Merchant Marine Academy of Genoa has resulted in the development of an advanced multimodal system. This system employs the Facial Action Coding System (FACS) and the Geneva Minimalistic Acoustic Parameter Set (GeMAPS) for real-time analysis and response to human emotions aboard naval vessels.
The aim is to personalize maritime spaces, ensuring safety and well-being for passengers by capturing and responding to the emotional nuances of clients. The research incorporates various sensory modalities, including facial expression and vocal prosody to achieve a comprehensive understanding of emotions. Initial findings demonstrate the system's potential in creating emotionally resonant environments, with applications in romantic, adventure, wellness cruises, and more.
The methodology combines video and audio analysis, self-assessments, and expert evaluations to ensure data coherence.
Future work will explore the integration of Virtual Reality (VR), Augmented Reality (AR), non-invasive biometric sensors, and electroencephalography (EEG) to deepen emotional understanding and further personalize the sea travel experience.
This innovative convergence of technology and empathy in naval design promises to revolutionize the concept of sea travel, making it a more intimate and responsive journey.

Keywords

1. Naval Design
2. Emotional Intelligence
3. Multimodal Analysis
4. Adaptive Maritime Spaces
5. Biometric Integration

Introduction

The ongoing evolution of sea travel experiences takes a leap forward in our research, a result of collaboration between the Ph.D. program in Marine Science and Technology, specializing in Naval and Nautical Design at the University of Genoa, and the Merchant Marine Academy of Genoa. Our pioneering study focuses on the creation of an advanced multimodal system, initially centred on facial expression recognition (FACS), and subsequently expanding to the analysis of prosody and speech (GeMAPS). Positioned at the intersection of technology and empathy, this system promises to redefine nautical naval design, shaping an unparalleled sea travel experience.

In the current dynamics of naval design, the advanced integration of technology and human sensitivity emerges as a key element. Our investigation aims to explore this fusion, charting an innovative path to elevate the sea travel experience. At the core of this revolutionary approach lies artificial intelligence (AI) and its ability to analyse emotions, fundamentally transforming the naval designer's perspective in crafting personalized vessels.

The design of a naval unit today goes beyond aesthetics and functionality, delving deep into the realm of emotions and experiences. Our goal is to capture the emotional nuances of the client, paving the way for a new paradigm that goes beyond mere boat construction: we are constructing a tailor-made emotional experience.

Imagine surpassing technical requirements and practical design aspects, delving into the world beneath tangible surfaces, understanding the desires, preferences, and emotional nuances of the client. This not only enables a more profound customization but transforms the vessel into an authentic extension of the client, capable of reflecting their personality, lifestyle, and unique emotions.

In this context, the change is profound. The naval designer's decision-making process no longer confines itself to technical and aesthetic aspects; now, a new space opens up for the incorporation of artificial intelligence and emotion analysis. Design becomes an empathic dialogue with the client, a deep investigation of their emotions, and a translation of these emotions into tangible elements of naval design.

Emotion analysis permeates every aspect of design, from material selection to space arrangement, from lighting configuration to furniture details. A client seeking a relaxing experience may enjoy warm colour palettes and an open layout, while those seeking strong emotions may appreciate a bold and dynamic design (fig.1).

Figure 1: Possible Client's customization

The use of AI in emotion analysis is not just a resource for customizing design but is an open window into a deep understanding of the client's needs and expectations. The naval designer becomes an "emotion reader," interpreting not only explicit requests but also implicit desires. Design thus becomes a collaborative and participative process, where every decision is based on an intimate understanding of the client's emotions.

This convergence of naval design and artificial intelligence is not only an enrichment of the designer's practice but translates into significant added value for the client. Every aspect of the vessel becomes infused with emotional meaning, transforming sea travel into a profoundly personal experience. Emotion analysis becomes a guiding beacon for the designer, directing design choices toward a result that is not just a boat but a tangible testament to the client's emotions and unique experiences at sea. In this rapidly evolving landscape of naval design, the interaction between advanced technology and human sensitivity emerges as a crucial relevance. Our research aims to explore this fusion, outlining an innovative approach to enhance the sea travel experience.

Research Goals

Our research aims to create a system that not only recognizes but interprets and responds to human emotions on board a naval unit. The goal is to transform maritime space into an empathic and personalized environment, enhancing the safety and well-being of passengers.

Emotion Recognition through FACS and GeMAPS

Our journey began with the implementation of the Facial Action Coding System (FACS), developed by Ekman and Friesen, for facial expression analysis. Each movement of a facial muscle is encoded, and the combination of these movements provides a precise reading of emotions (FER – Facial Emotion Recognition). Analysis of video frames through a machine learning algorithm resulted in the ability to identify the most probable emotion experienced every second of recording. However, we did not stop there. We broadened our perspective by utilizing the Geneva Minimalistic Acoustic Parameter Set (GeMAPS) to create a vector for prosody and speech analysis. In this case, too, we successfully extracted the most probable emotion every two minutes. The combination of results from these two analyses allowed us to achieve a deep and multimodal understanding of emotional states.

A multimodal system for emotion analysis is an approach that uses different sensory modalities to acquire information about human emotions. Common modalities involved in a multimodal system include facial expression analysis, vocal prosody, body posture, body language, body temperature, and other biometric signals. The goal is to obtain a more comprehensive and accurate understanding of human emotions by integrating information from various sensory sources.

The primary modalities involved in a multimodal system for emotion analysis include:

- Facial Expressions: Facial expression analysis involves the detection and interpretation of facial muscle movements, often using systems like the Facial Action Coding System (FACS). This approach identifies emotions such as happiness, sadness, anger, and so on.
- Vocal Prosody (GeMAPS): Prosody pertains to rhythmic and melodic patterns in intonation and vocal characteristics during verbal

communication. Analysing vocal prosody helps identify emotional tones, stress levels, or emphasis in vocal communication.

- Body Posture and Body Language: Body posture and body language are non-verbal modalities that provide information about an individual's emotional state. Changes in posture, gestures, or body movements can indicate different emotions or moods.
- Biometric Signals: Some multimodal systems may involve measuring biometric signals such as heart rate, body temperature, or brain activity through electroencephalography (EEG). These data can provide additional details about emotional states.
- Text and Language: Analysis of written or spoken language can be integrated into the system by examining keywords, writing tone, or speech to gather further clues about emotions.

During our first year of research, we dedicated ourselves to the advanced integration of emotion analyses, with a particular focus on interpreting facial expressions and vocal prosody. Our main objective is the creation of an innovative system that not only limits itself to emotion recognition but can adapt naval spaces in real-time (fig.2).

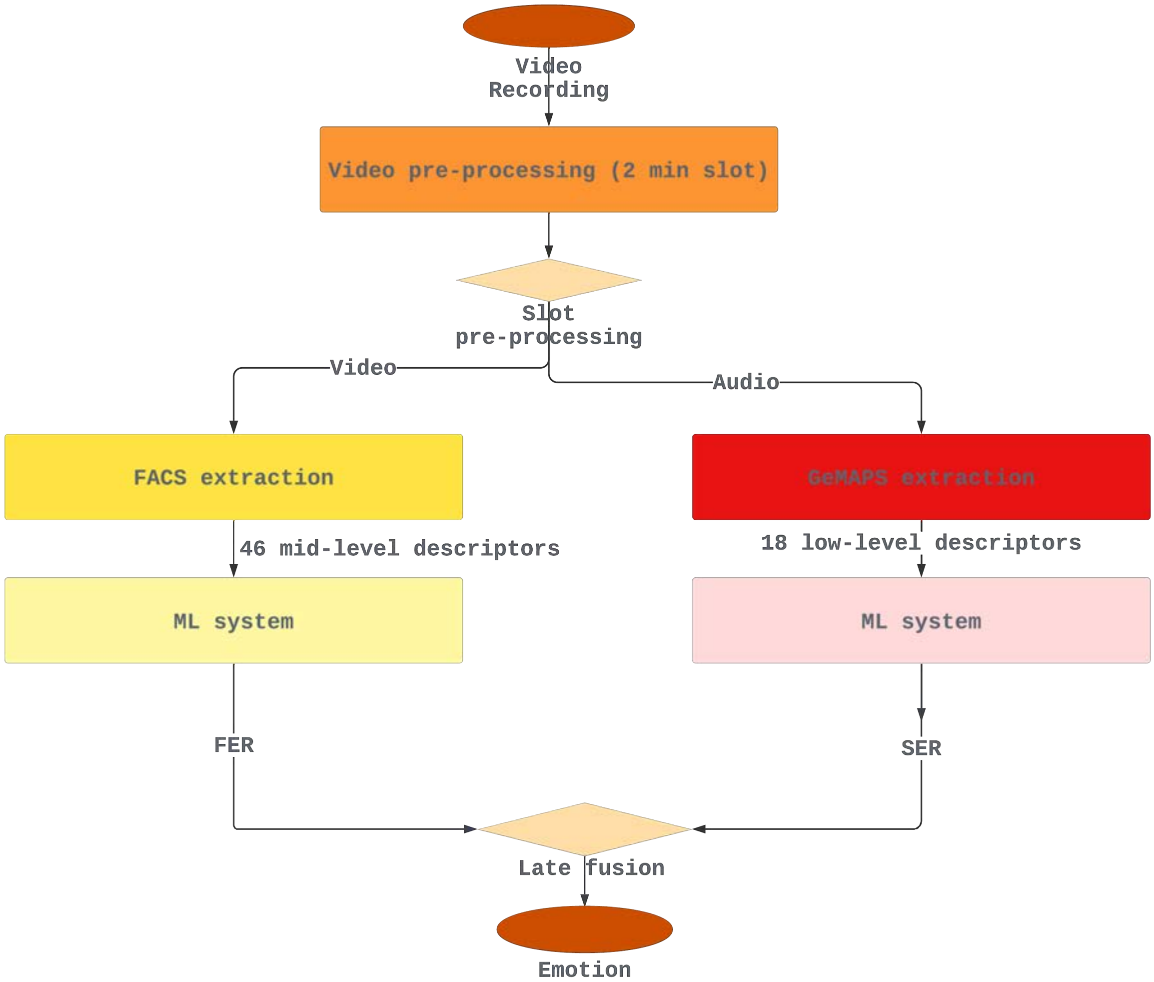

Figure 2: Our research multimodal system

Possible application scenarios

Let's explore some possible simple application scenarios where our system could be useful:

- Romantic Cruise
    - Environment Customization: Based on facial expression and prosody recognition, the system can interpret guests' emotional states. If it detects a romantic atmosphere, it will adjust lighting to warm tones, select suggestive music, and create more intimate spaces.
    - Emotion Detection: Continuously monitoring guests' expressions and voices, the system can dynamically adapt the onboard experience, offering personalized services such as candlelit dinners or romantic excursions.
- Adventure Trip:
    - Dynamic Configuration: During high-adrenaline activities, the system can intensify lighting and the soundtrack, enhancing the feeling of excitement. For example, during turbulent waters

navigation, the system can create a captivating and stimulating atmosphere.
    - Stress Monitoring: The system analyses the facial expressions of the crew to identify signs of stress. In response, it can provide emotional support through reassuring messages, reducing overall anxiety.
- Wellness Cruise:
    - Creation of Regenerating Spaces: Using emotion recognition, the system can identify moments when guests seek relaxation and tranquillity. It will create spaces with soft lighting, oceanic sounds, and calming aromas.
    - Real-time Emotional Feedback: Guests can receive personalized feedback on the effectiveness of relaxation practices, such as yoga or meditation. The system adjusts sessions to maximize emotional well-being.
- Onboard Gastronomic Experience:
    - Sensory Pairings: By analysing expressions during tastings, the system can suggest optimal sensory pairings. For instance, if it detects a particular appreciation for a dish, it will modify the onboard environment to emphasize that gustatory experience.
    - Adaptation to Preferences: The system tracks guests' emotional preferences and creates personalized gastronomic experiences, adapting the menu and atmosphere to maximize satisfaction.
- Navigation in Adverse Weather Conditions:
    - Stress Management: Detecting signs of stress during adverse weather conditions, the system can adjust the indoor environment. For example, it may dim lights to create a more reassuring atmosphere and provide soothing entertainment to distract the crew.
- Educational Experience Onboard:
    - Creation of Educational Environments: Analysing students' emotional reactions during lessons, the system can adjust lighting and audio to create an optimal learning environment.
    - Personalized Feedback: The system tailors educational material based on students' emotional reactions, creating a personalized learning experience that stimulates interest and participation.

These scenarios illustrate the revolutionary potential of our system in transforming the sea travel experience into something truly extraordinary and personalized (fig.3).

Figure 3: Setting customization.

Methodology

The methodology adopted for this study is based on a holistic approach that embraces the multidimensionality of emotional experiences on board through the analysis of facial expressions, prosody, and verbal interactions. The objective is to acquire accurate and rich data, crucial for understanding the emotional experience of occupants during port simulations.

Participants

The recordings were made during the recruitment phase for the officer cadet position and we recorded 31 students. The recruitment pool comprised 25 males and 6 females, ranging in age from 19 to 23, and representing diverse backgrounds. The choice of realistic scenarios aimed to elicit a broad spectrum of emotions, enabling a comprehensive analysis of emotional responses.

Multimodal Data Acquisition

Video recording was conducted during a recruitment session, focusing on students' facial expressions, and capturing dialogues through directional microphones. This approach allows for a comprehensive assessment by combining visual and acoustic data.

Facial Expression Analysis (FACS)

Facial expressions were analysed using the Facial Action Coding System (FACS) developed by Ekman and Friesen. This system enables detailed coding of facial expressions in terms of muscle movements. The precision of FACS provides a thorough understanding of manifested emotions. We were able to determine the most probable emotion experienced by the student every second of the interview. We analysed emotions using Morphcast platform (fig.4), using HumeAI tools (fig.5) and using our code, internally developed.

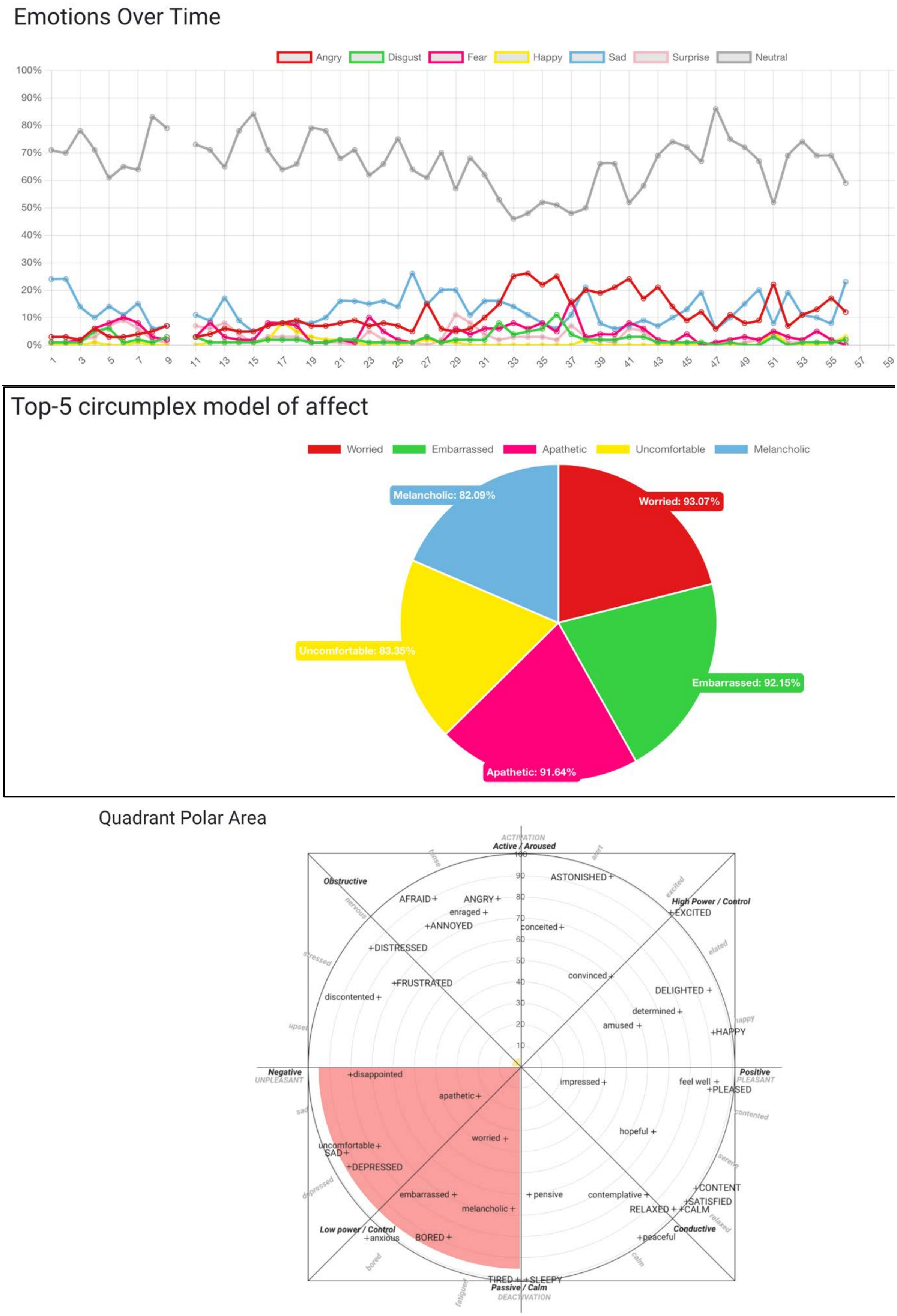

Figure 4: Emotion Detection during an interview slot using Morphcast

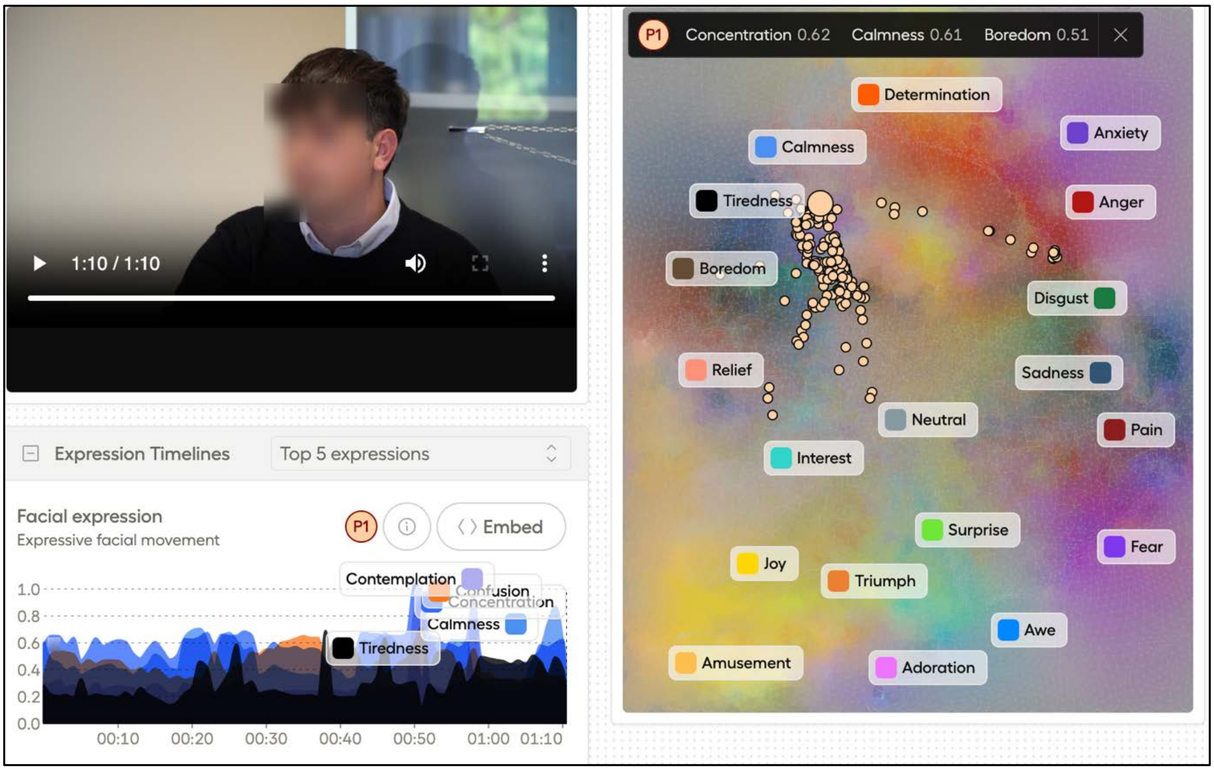

Figure 5: Emotion Detection during an interview slot using HumeAI

Prosody and Speech Analysis (GeMAPS)

Parallel to facial expression analysis, acoustic analysis was conducted through the Geneva Minimalistic Acoustic Parameter Set (GeMAPS). This system focuses on fundamental acoustic parameters, allowing a detailed assessment of nuances in voice intonation and modulation. In this case, video streams were analysed to extract the most probable emotion every 2 minutes.
We used openFace system (fig.6), HumeAI tools (fig.7) and our code.

Figure 6: SER using openFace system

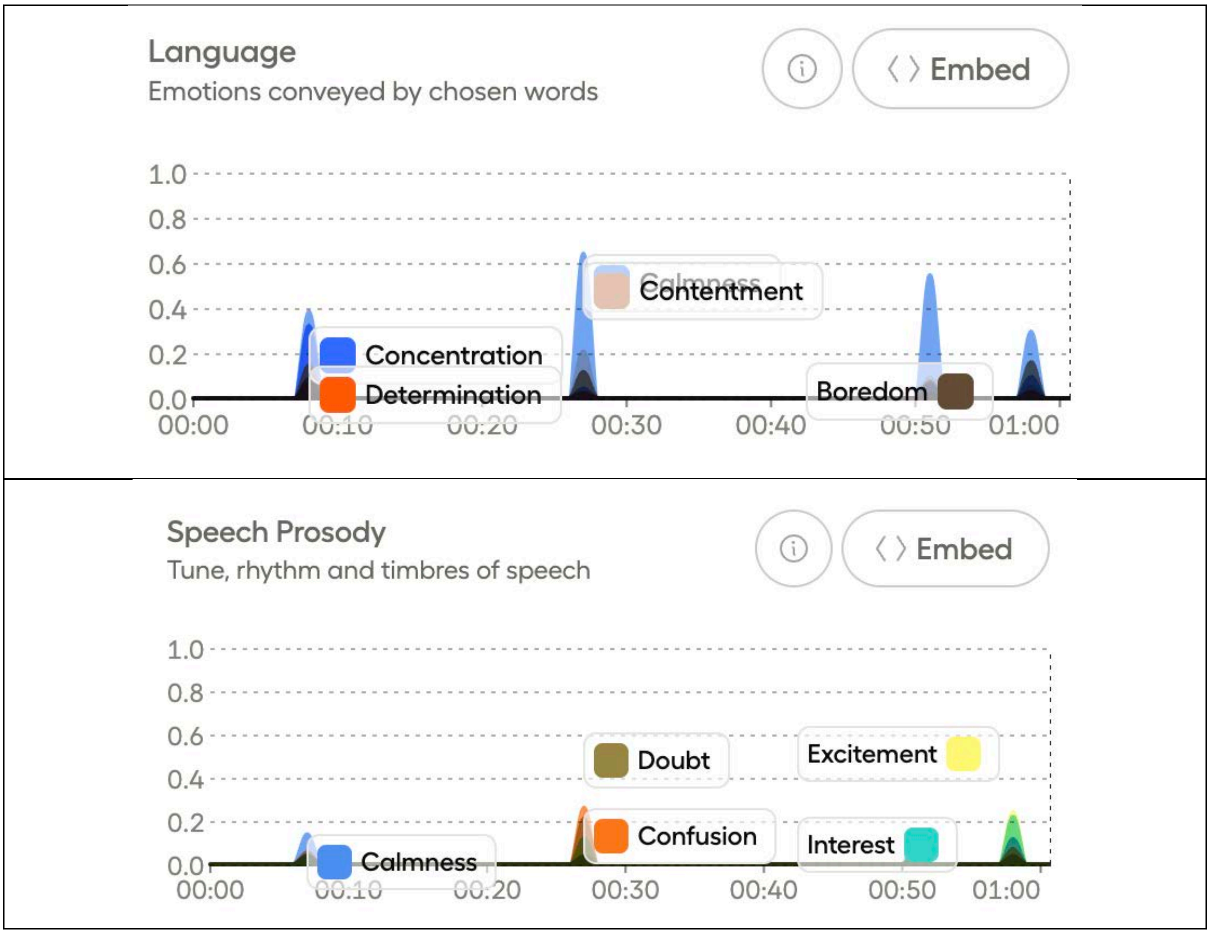

Figure 7:: SER using HumeAI tools

Self-Assessment and Questionnaires

At the end of the simulations, students completed a detailed questionnaire. The first part listed 38 emotions, requiring participants to rate the degree of emotional experience on a scale from 0 to 4 (fig.8). The second part used the Self-Assessment Manikin (SAM), evaluating arousal, and valence of emotions (fig.9).

During the questionnaire, a few common issues were encountered, such as:

- Response bias, which is the inclination of participants to respond in a manner they perceive as socially acceptable or in line with what they assume the interviewer expects. This can result in data that is not entirely accurate or comprehensive.
- Self-assessment bias. This happens when individuals find it challenging to evaluate and articulate their own emotions precisely, using a consistent set of words and definitions. Given that emotions are intricate and personal, interpretations of the same feelings can vary from person to person.

It was noted that many emotions, especially when felt strongly, were accurately recognized, including feelings of amusement, delight, conviction, and happiness. However, participants struggled to identify emotions like conceit and discomfort.

Furthermore, there was a problem with the clear differentiation of many emotions, as several students reported being unfamiliar with the precise meanings of the terms provided.

Expert Evaluation

An expert mind anthropologist in paraverbal communication evaluated students' performances in terms of manifested emotions. This external assessment adds a level of objectivity and confirms the consistency between objective data and human perception.

HOW DID YOU FEEL?
COME TI SEI SENTITO DURANTE L'ESERCITAZIONE?

English	Italiano	Per niente: 0	Un po': 1	Abbastanza: 2	Molto: 3	Moltissimo: 4	Non so
Afraid	Paura						
Amused	Divertito						
Angry	Arrabbiato						
Annoyed	Infastidito						
Anxious	Ansioso						
Apathetic	Apatico						
Aroused	Eccitato						
Astonished	Stupito						
Bored	Annoiato						
Calm	Calma						
Conceited	Presuntuoso						
Contemplative	Contemplativo						
Content	Contenuto						
Convinced	Convinto						
Delighted	Incantato						
Depressed	Depresso						
Determined	Determinato						
Disappointed	Deluso						
Discontented	Scontento						
Distressed	Angosciato						
Embarrassed	Imbarazzato						
Enraged	Infuriato						
Excited	Eccitato						
Feel Well	Sentirsi bene						
Frustrated	Frustrato						
Happy	Contento						
Hopeful	Speranzoso						
Impressed	Impressionato						
Melancholic	Malinconico						
Peaceful	Tranquillo						
Pensive	Pensieroso						
Pleased	Lieto						
Relaxed	Rilassato						
Sad	Triste						
Satisfied	Soddisfatto						
Tired	Stanco						
Uncomfortable	Scomodo						
Worried	Preoccupato						

Figure 8: Emotional Survey for each participant

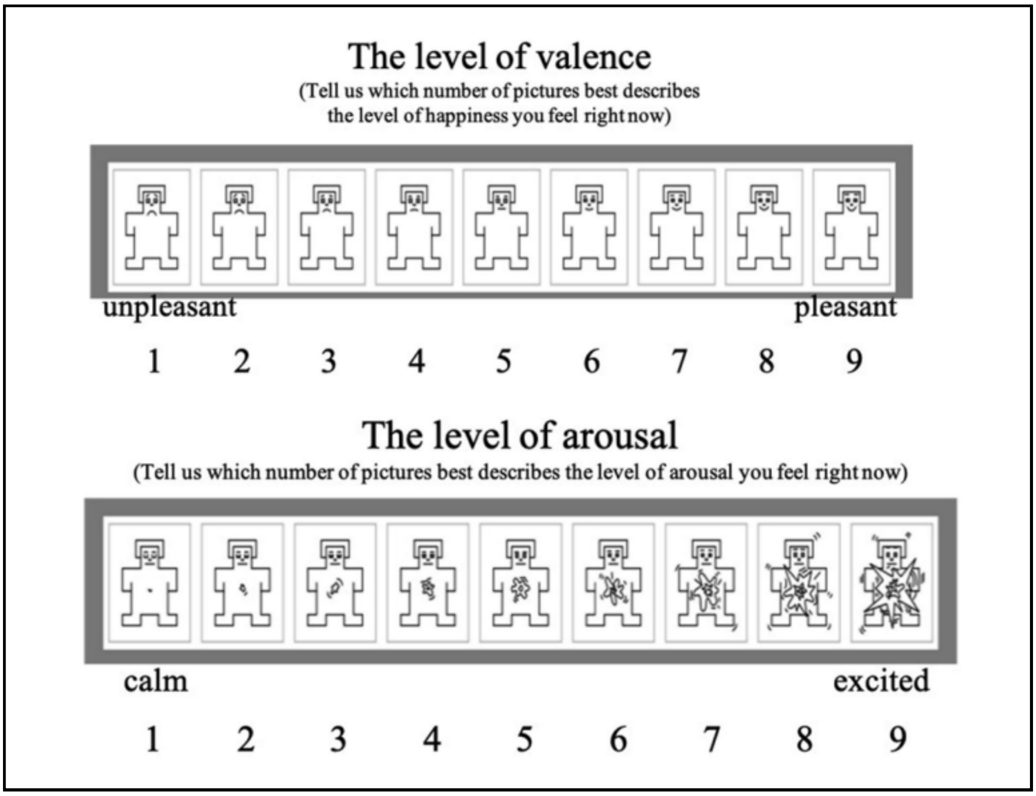

Figure 9: Self-Assessment Manikin questionnaire

Data Analysis

Data collected from various sources were integrated for a comprehensive understanding.

We processed videos and audios, and we compared the results with the data obtained from the questionnaire using the emotion recognition model to map data with the valence-arousal 2D discrimination (Dai, Wang, Zhang, Zhang & Chen, 2018) such as in figure 11.

Comparative analysis involved the convergence between objective results, self-assessments, and external evaluations. This process aims to ensure the coherence and validity of the collected data.

This multidisciplinary methodology is designed to capture the richness of emotional experiences on board, allowing for a thorough and detailed understanding. The combination of objective and subjective data is crucial for drawing meaningful conclusions and guiding the future development of advanced emotion recognition systems in naval nautical design.

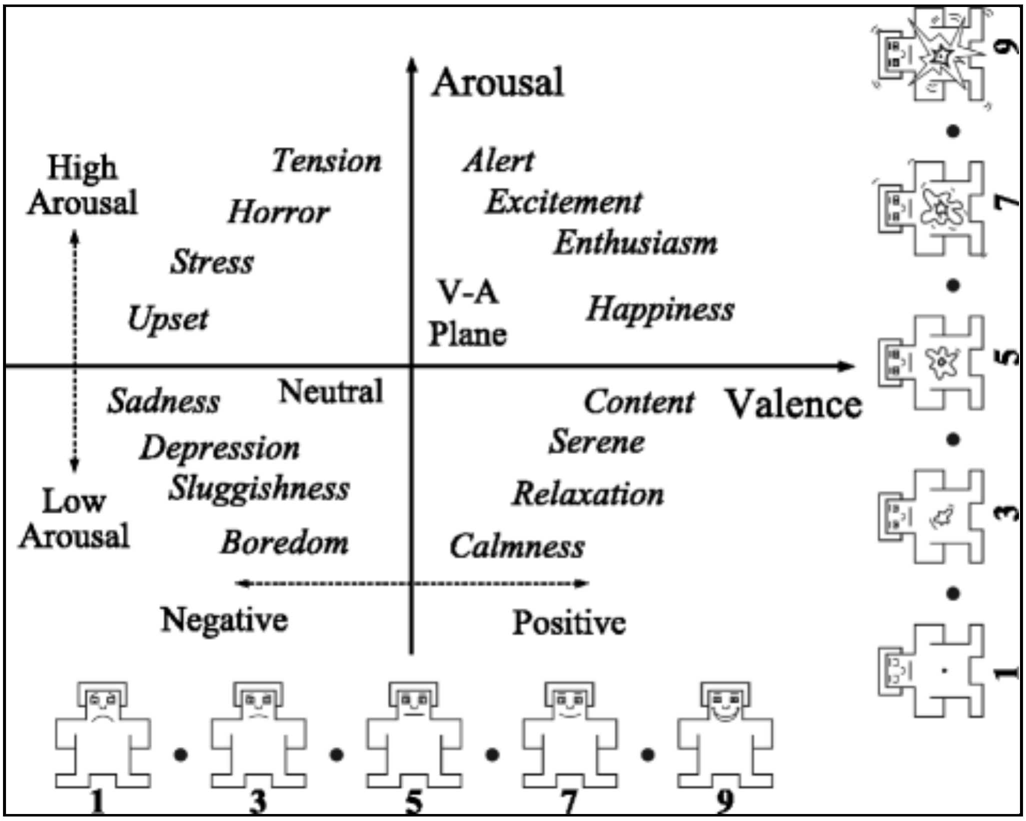

Figure 10: Valence-Arousal plane and 2-D SAM (Self-Assessment Manikin) questionnaire. Image taken from Dai, Yixiang & Wang, Xue & Zhang, Pengbo & Zhang, Weihang & Junfeng, Chen. (2018).

Ethical Considerations and Privacy

Responsible data management has been a priority throughout this study. All students provided informed consent, and privacy was ensured during all phases of the experiment.

Future Directions: Expanding the Horizons

The strides made in this research not only signify progress but also pave the way for promising developments set to redefine the realm of nautical naval design. Amidst the plethora of opportunities that unfold, one particularly captivating and revolutionary trajectory emerges through the seamless integration of Virtual Reality (VR) and Augmented Reality (AR).

Virtual Reality (VR) Integration:

- Immersive Voyage: The utilization of virtual reality goggles stands poised to metamorphose the vessel's interior into an entirely novel realm. Occupants, by immersing themselves in virtual environments that resonate with their moods or emotional inclinations, have the potential to craft a distinctive onboard experience.

- Tailored Simulations: VR holds the promise of facilitating bespoke simulations, empowering users to "test" diverse design configurations and explore interior spaces before the physical construction of the vessel commences. This approach not only heightens customer satisfaction but also streamlines the design process.

- Dynamic Adaptation: Virtual environments, in this context, can dynamically respond to detected emotions, dynamically adjusting colours, lighting, and acoustics to meet the emotional needs of the occupants in real-time.

Augmented Reality (AR) Integration:

- Contextualized Enrichment: Augmented reality tools offer occupants the ability to access context-aware information about their surroundings, enriching the sailing experience with personalized and informative details.

- Interactive Design: AR's potential lies in enabling users to interact directly with virtual elements superimposed on the real environment. For instance, occupants could easily customize furniture arrangements or alter the lighting scheme with a simple gesture.

- Navigational Support: AR tools could serve as invaluable navigational aids, providing real-time information on points of interest, weather conditions, or the status of the vessel.

The amalgamation of Virtual and Augmented Reality not only signifies a leap forward in the realm of onboard experience but also expands the paradigm of participatory design, actively involving occupants in the creative process. These advancements usher in an era where technology not only reacts to identified emotions but transforms into an intelligent travel companion, dynamically enhancing and adapting the maritime experience.

Concluding Thoughts

In summary, our ground-breaking exploration into the field of nautical naval design through emotion analysis has not only opened novel vistas but also delineated innovative scenarios for the onboard journey. However, we envision further possibilities to enhance our multimodal system, transcending the confines of currently considered modalities.

The subsequent phase of our research is oriented towards integrating non-invasive biometric sensors, encompassing elements such as body temperature and heart rate detectors. Incorporating these critical metrics offers an additional layer to comprehend the emotions of occupants during voyages, with body temperature providing insights into comfort and well-being levels and heart rate potentially correlating with specific emotional states.

Additionally, we are delving into the prospect of integrating electroencephalography (EEG) systems into our multimodal approach. This audacious step holds the promise of directly tapping into the cerebral activities of occupants, fostering a profound understanding of their emotional responses. EEG, with its potential insights into emotional engagement and attention, becomes instrumental in further customizing the onboard experience based on users' cognitive requirements.

In essence, we look ahead with anticipation, guided by the vision to forge an even more sophisticated and occupant-centric multimodal system. The integration of biometric sensors and EEG systems emerges as a substantial stride towards the realization of a highly personalized and intuitive maritime environment, one that adeptly mirrors and dynamically adjusts to the intricate facets of human emotions.

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