RESEARCH REPORT

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Human-technology interoperability and artificial emotional intelligence Final Report

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Summary

The HIPE project has demonstrated the technical feasibility and practical value of emotion-aware services in physical spaces, leveraging advances in multimodal sensing, AI-driven analytics, and collaborative system design. Proof-of-concept implementations in public transport and meeting environments have shown that real-time emotion, behaviour and activity indicators based on group-level measurements can enhance user experience, safety, and operational efficiency. These results highlight the potential for adaptive environments that respond to collective mood and engagement, supporting more human-centric and responsive services. However, several challenges remain for broader adoption, including technical limitations in emotion recognition accuracy, integration of diverse sensor types, scalable data fusion pipelines, and compliance with privacy regulations such as GDPR and AI Act. The lack of harmonization in regulatory definitions and liability frameworks creates uncertainty for developers and users, while the focus on data identification in privacy regulation risks making compliance impractical for future AI systems. From a business perspective, the market for emotion-aware services is poised for growth, driven by increasing demand for personalized, adaptive environments in sectors like transportation, offices, and retail. Realizing this potential depends on overcoming technical, regulatory, and cultural barriers, as well as developing sustainable business models. The HIPE Perceptor concept, while promising, illustrates the need for ongoing innovation in sensing technologies, algorithms, and privacy solutions. Ultimately, the responsible deployment of emotion-aware services will require a balance between technological capability, ethical principles, and legal compliance, supported by clear regulatory guidance and positive incentives for innovation.

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Preface

This report presents the outcomes of the HIPE (Human-technology Interoperability and Artificial Emotional Intelligence) project, which was carried out by a multidisciplinary research consortium, consisting of experts in technology, business, and law. The project was coordinated by VTT Technical Research Centre of Finland Ltd and involved close collaboration with partners from academia and industry. The work was motivated by the growing need for intelligent environments that not only automate tasks but also understand and adapt to human emotions, behaviours, and cultural contexts. Throughout the project, the consortium focused on developing and validating emotion-aware services, advancing sensor technologies, and addressing the complex regulatory and ethical challenges associated with emotional AI. The achievements and insights documented here reflect the dedication and expertise of all partners, as well as the valuable feedback from stakeholders and end-users. We hope this report will inform future research, innovation, and responsible deployment of emotion-aware technologies in society.

Oulu, 24.3.2026

Sari Järvinen

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1. Introduction

The HIPE (Human-technology Interoperability and Artificial Emotional Intelligence) project addresses the growing need for seamless interaction between humans and intelligent systems in increasingly digitalized environments. As technology becomes more embedded in everyday life, the challenge lies in ensuring that these systems not only respond to functional requirements but also understand and adapt to human emotions, behaviours, and cultural contexts. The background of the problem is rooted in the rapid evolution of smart spaces, where emotion-aware services and adaptive environments are expected to enhance user experience, safety, and efficiency. However, this evolution brings forth complex issues related to human rights, data privacy, regulatory compliance in general, and the ethical use of artificial intelligence.

The HIPE project was conceived to explore and advance the interoperability between humans and technology, with a particular focus on artificial emotional intelligence. The research theme centres on developing and testing emotion-aware services, smart lighting, and human behaviour modelling within real-world environments. By bringing together a consortium of companies, research institutions, and other collaborators, HIPE aimed to create proof-of-concept solutions that demonstrate the practical value and feasibility of emotion-aware technologies.

Throughout the project, key technical achievements included the development of multimodal sensing environments, advancements in remote sensor technologies, and the integration of AI-driven analytics for real-time activity and emotion detection. The project also tackled significant regulatory and ethical challenges, mapping out the landscape of privacy regulations, the emerging AI Act, and the need for harmonized legal definitions and incentives. Importantly, HIPE highlighted the variability in cultural acceptance of monitoring technologies and the impact of regulatory frameworks such as GDPR on the deployment of emotion-aware systems.

This public final report provides a comprehensive overview of the HIPE project, summarizing its objectives, consortium collaboration, main results, and recommendations for future development. The findings underscore the importance of balancing technological innovation with ethical and legal considerations, paving the way for more human-centric and trustworthy intelligent environments.

2. Emotion-awareness and related technologies

The vision of HIPE was and still is to enhance physical spaces with emotionally aware, intelligent, and integrated services that can respond to the demand and expectations of the users. Technical solutions for such awareness exist, but mostly as research findings, on very low TRL. Our challenge in HIPE was to close the large gap between the fragmented, service-specific experimental laboratory prototypes and commercially feasible services.

Human emotion and behaviour can be detected using different approaches. The use of cameras can provide versatile information. Standard video material can be processed for e.g. detecting people and objects, identification of actions, and analysis of facial expressions. Depth cameras record three-dimensional information which allows more reliable gesture detection, analysis of poses and directions, as well as enable separating targets overlapping in two-dimensional data. There are often privacy concerns related to camera-based monitoring, particularly in more private spaces, such as meeting rooms and offices. By implementing on-site processing, which stores and moves on only the higher-level parametric information, these concerns can be mitigated.

Measurement of biosignals provides information of the psychophysiological state of the people. Emotions and other mental states stimulate the autonomous nervous system (ANS), which regulates e.g. cardiac function, breathing, skin conductivity and blood pressure. ANS activity is particularly sensitive to arousal level and acute stress. Monitoring the eye movements can provide information not only about the gaze direction, but oculomotor behaviour, which is linked to ANS and can provide complementary information to the physiological signals, e.g. indicate alertness and tiredness. Biosignals are often measured using wearable sensors, which is not always feasible in public spaces. Solutions exist for remote, non-contact biosignal monitoring (e.g. camera-based, radar-based sensors) and non-wearable contact sensors (e.g. seat foil sensors). These sensors are embedded in the space itself and do not require any effort or commitment from users of the space. Biosignal monitoring has similar privacy issues as camera-based setups, and similar solutions can be applied.

AI, particularly machine learning, is often used in classification of monitoring data into different emotions and mental states. However, the recent rapid advances in generative AI have made e.g. large language models (LLMs) an option in direct analysis of human behaviour and emotional state. LLMs can be applied to camera data, still images of video material, and asked to describe the content. With tailored prompts, they can provide not only qualitative but also quantitative information of people, actions and situation. Generative AI is a constantly evolving field, and model capabilities that were science fiction yesterday, will be reality tomorrow.

HIPE relies on multisensory monitoring of human behaviour (pose, gaze direction, interactions with tools), biosignals (heart rate, speaking) and camera-based data (AI-based situational interpretation from still images, facial expression reading from videos), along with environmental parameters (temperature, sound). Monitoring data are then converted into situational awareness and insights, which can, in virtually real time, drive actions.

In HIPE context, the interest is not on individuals but groups. In addition to group-level averages of individual states, e.g. dominant emotions, arousal states or behaviour types, true group features can be extracted. These features are often related to synchrony: how similar is a state or change in a state among the individuals in the space?

As the information needs and the feasibility of various monitoring solutions depend on the use case, the ensemble of monitoring sensors is tailored for each environment. The HIPE sensor implementation used in HIPE PoCs is presented in Chapter 5 Results.

3. Project background and objectives

The starting point for HIPE was the recognition that while technology is increasingly capable of automating tasks and providing functional services, it often lacks the ability to understand and adapt to the emotional and behavioural nuances of human users. This gap presents both a challenge and an opportunity: to create intelligent environments that are not only efficient but also emotionally aware, ethically sound, and legally compliant.

The project set out to address several key questions:

- How can technology be designed to interpret and respond to human emotions in real time?
- What are the technical, ethical, and legal barriers to deploying emotion-aware services in public and private spaces?
- And how can these solutions be made scalable and commercially viable, while respecting privacy and regulatory frameworks such as the GDPR and the emerging AI Act?

HIPE's objectives were ambitious and multifaceted. The project aimed to develop modular technology components and solutions for emotion analytics, leveraging artificial intelligence to interpret biosignals and motion data. The ultimate goal was to enhance user experience, safety, and well-being in various environments (e.g. workplaces, public spaces, and transportation) by enabling systems to detect emotional states, anticipate needs, and respond appropriately. The project also sought to bridge the gap between experimental prototypes and commercially viable services, empowering participating companies to build competitive digital solutions that prioritize human behaviour, emotions, and situational awareness.

A holistic research approach was adopted, considering the desirability, viability, and feasibility of emotionally intelligent services from both business-to-business (B2B) and business-to-consumer (B2C) perspectives. Legal and ethical aspects were central to the research process, with a strong emphasis on developing guidelines and best practices for the responsible use of emotional data. Proof-of-concept demonstrations in real-world settings were used to validate the technology and inform future commercialization strategies.

4. Project consortium and collaboration

The success of HIPE relied on the collaboration of a diverse consortium, bringing together expertise from research, technology, business, and law. The project was coordinated by VTT Technical Research Centre of Finland Ltd.

The roles and objectives of HIPE consortium partners complemented each other:

- **VTT Technical Research Centre of Finland Ltd** (Coordinator): *Leading research and development in AI, analytics, and service innovation.* VTT's objective in HIPE was to advance human-technology interoperability with a particular focus on artificial emotional intelligence. This included developing and testing emotion-aware services and human behaviour modelling within real-world environments. VTT was responsible for the development of multimodal sensing environments, advancements in remote sensor technologies (such as radar, seat foil sensor, and both RGB and depth cameras), and the integration of AI-driven analytics for real-time activity and behaviour analysis. Additionally, VTT played a central role in ensuring that the project's solutions were practical, scalable, and aligned with both technical and ethical standards.
- **University of Lapland**: *Providing expertise in legal and ethical aspects, through the Faculty of Law.* The university of Lapland experts ensured that legal and ethical considerations were integrated into the project from the outset, contributing to the development of guidelines and best practices for the responsible use of emotional data and emotion-aware technologies. Their involvement helped the consortium address regulatory challenges, such as privacy regulations, the emerging AI Act, and the harmonization of legal definitions and incentives.
- **Ambientia**: *A software house specializing in integration, automation, and service design for IT systems, including industrial IoT and mobile applications*. Ambientia's objective in HIPE was to contribute its expertise in software development and service integration, supporting the creation and implementation of emotion-aware technologies and to evaluate the potential of emotion-aware solutions from their business perspective. By collaborating with other partners, Ambientia helped ensure that the developed solutions could be effectively integrated into real-world IT environments, making them practical, scalable, and commercially relevant.
- **Framery**: *A global leader in engineering and manufacturing soundproof pods and solutions for modern work environments.* Framery's role in the project was to support the development and demonstration of emotion-aware technologies in authentic work settings, ensuring that the solutions created were practical, user-centred, and commercially relevant. Their objective was to learn from the potential emotion-awareness would bring to their products.
- **Helvar**: *An international company specializing in intelligent lighting solutions and digital services for smart spaces*. In HIPE project, Helvar focused on developing a multimodal sensing environment as part of the project's technical achievements. This involved advancing

sensor technologies and integrating them into smart environments to support emotion-aware services. Helvar also collaborated with other partners to test how these technologies could be applied in real-world use cases.

- **Isku**: *A long-established designer and manufacturer of furniture for public spaces, offices, and homes, with operations across the Nordics, Baltics, Poland, and the Near East*. Isku's objective in the HIPE project was to provide domain-specific knowledge and real-world application environments for piloting and validating emotion-aware solutions. By collaborating with other partners, Isku helped ensure that the developed technologies could be tested and demonstrated in authentic settings, supporting the project's goal of creating practical, user-centred, and commercially relevant emotion-aware services.
- **Teleste**: *An international technology group providing security and information technologies, including passenger information and security video solutions with advanced data analytics.* Teleste's main objective in the project was to contribute its expertise in security and information technologies, specifically by piloting and validating emotion-aware services in real-world environments. Teleste worked closely with other consortium partners to integrate emotion-aware features into its systems, such as enhancing passenger information and security video solutions with advanced data analytics. In the project, Teleste's system was used as a platform for proof-of-concept demonstrations (such as in the tram use case) where emotion-aware technologies were tested to complement existing solutions. The feedback from these pilots, including input from tram drivers, helped assess the added value and practical feasibility of emotion-aware services, focusing on real-time indicators and privacy-preserving approaches.

Each partner contributed unique strengths: VTT led the research and technology development; the University of Lapland ensured that legal and ethical considerations were integrated from the outset; Ambientia, Framery, Helvar, Isku, and Teleste brought domain-specific expertise and real-world application environments for piloting and validating the solutions.

The consortium's collaborative model was built around co-creation and proof-of-concept implementations, with regular workshops and joint action planning. This approach fostered knowledge sharing, rapid iteration, and the development of solutions that are not only technologically advanced but also ethically robust and commercially relevant.

5. Results and key achievements

5.1 Main technical results

This section presents the main technical results of the HIPE project, building on the rapidly evolving landscape of smart environments and emotion-aware technologies. As digitalization transforms physical spaces, there is a growing demand for systems that not only automate tasks but also understand and respond to human emotions, behaviours, and situational contexts. The state-of-the-art in this field involves the integration of diverse sensor technologies such as Bluetooth mesh networks, advanced cameras, radar, and environmental sensors combined with robust data fusion and AI-driven analytics. These innovations enable real-time detection of human activity and emotional states, supporting adaptive and privacy-aware services in workplaces, public transport, and other everyday environments. The HIPE project advances this frontier by developing scalable, collaborative sensor infrastructures and sophisticated data processing pipelines, laying the groundwork for reliable, human-centric intelligent environments that balance technological capability with ethical and legal considerations.

5.1.1 Sensor infrastructure

Development of emotion-aware digital services in physical environments necessitates implementation and integration of collaborative sensor infrastructures and advanced data fusion methods. Helvar's proof-of-concept platform demonstrated a flexible environment sensor mesh datalogger, capable of collecting and visualizing environmental parameters from freely locatable Bluetooth sensors. This system supports sensor fusion and meshing, allowing for improved feature extraction, positional correlation, and offline data processing, even in environments lacking network connectivity. The multimodal setup was essential for achieving robust and context-sensitive analytics in real-world environments. VTT developed a comprehensive people tracker pipeline, integrating raw data collection from various sensors—including 2D, stereo, and depth cameras—with edge computing for real-time analysis and high-level AI-enhanced analytics. The pipeline enables detection of human posture, group synchrony, and human-object interactions, with anonymized data transmission and local edge processing to ensure privacy. Additionally, the project advanced synthetic data generation for radar simulation, leveraging monocular motion capture and 3D modeling to create datasets for training and validating deep learning algorithms. Alternative sensing elements, such as thermal cameras and time-of-flight sensors, were also evaluated for their suitability in GDPR-compliant activity detection. Collectively, these technical achievements provide a robust foundation for reliable, scalable, and privacy-aware emotion and activity sensing in diverse real-world environments.

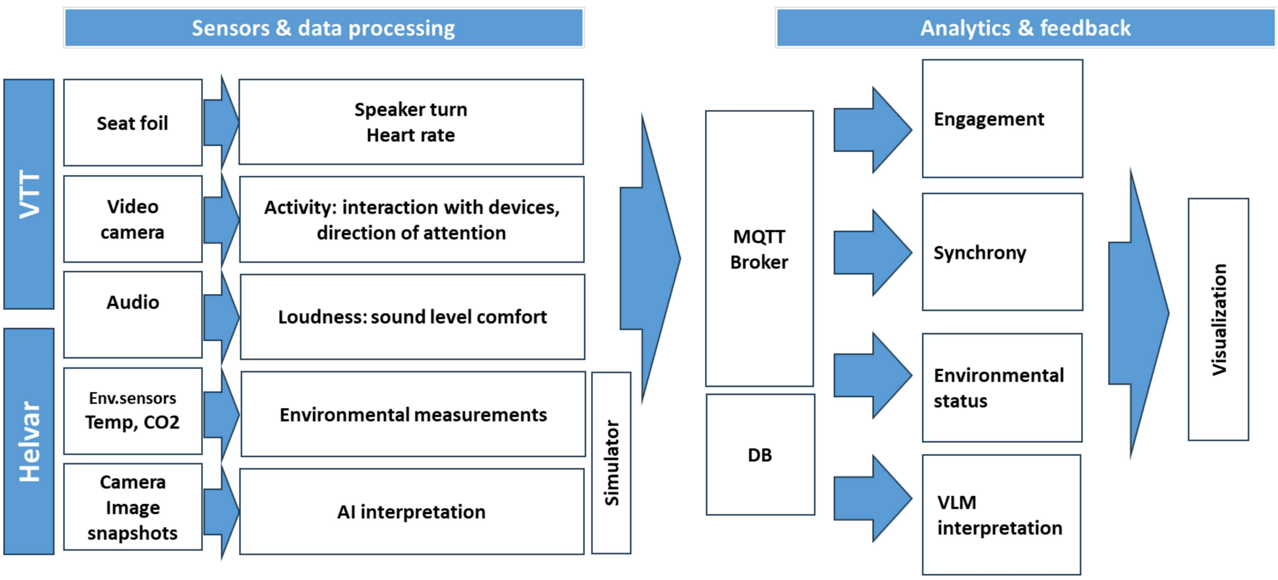

Figure 1. Sensor and data analysis integration framework.

5.1.2 Emotion recognition

WP3 developed novel machine learning algorithms and multimodal analytics methods to recognize relevant human emotions such as mood, stress, and concentration in both private and public environments. Emotion recognition was achieved by analyzing biosignals (e.g., heart rate, HRV), audio, and video data streams, with models optimized for both individual and group-level detection. For example, in public transport scenarios, on-board cameras and microphones were used to classify passenger emotions, enabling the calculation of a group mood index that could trigger service improvements if negative emotions persisted. The project also experimented with different modalities and parametrizations to increase detection accuracy and robustness across diverse real-life situations.

The main goal was to measure physiological indicators of emotional state using sensors that can operate at a distance, eliminating the need for wearable sensors. VTT experimented with two different sensor types for achieving this:

1) seat foil (SEFO) a thin, flexible sensor layer placed inside or under a chair cushion. It measures physiological signals, such as heart rate, respiration, and movement by detecting changes in pressure or force as a person sits. Seat foils enable contactless physiological monitoring without requiring the user to wear any devices, making them ideal for unobtrusive health and behaviour tracking in different environments. The seat foil experiments demonstrated that it is possible to reliably monitor heart rate (MAE less than 3bpm), HRV, movement, and even speech activity in a non-intrusive way, supporting the measurement of physiological signals related to emotional status and behaviour in everyday environments.

2) FMCW radar is a contactless sensor that uses millimetre-wave technology (specifically, 60 GHz FMCW radar) to detect and monitor people in a space. It can measure physiological signals such as heart rate and respiration, as well as track movement and presence. The radar works by emitting radio waves and analysing their reflections from the human body, enabling unobtrusive monitoring of physiological and behavioural states in real time. The radar experiments demonstrated that remote, contactless monitoring of physiological signals and movement is feasible and effective. Radar is especially strong in respiration monitoring and multi-person tracking, making it a valuable tool for situation awareness and behavioural analysis in environments where privacy and unobtrusiveness are important. Accuracy was sensitive to the exact positioning and parameter settings, and was generally lower than the seat foil sensor, especially during movement or when the subject's posture changed.

5.1.3 Human behaviour modelling

The work package advanced higher-level behaviour modelling by developing classification and prediction models that interpret heterogeneous, multimodal sensor data. These models enabled the analysis and prediction of individual and group behaviours, such as people flow, motion, and reactions, in dynamic physical spaces. The behaviour and emotion recognition framework for emotion-aware services in physical spaces (Figure 2) proposes a generalized model for real-time input of human behaviour and emotional state to emotionally intelligent services [6]. Sensor fusion and data quality were central themes, with the project focusing on combining data from various sources to improve the reliability and interpretability of behavioural analytics.

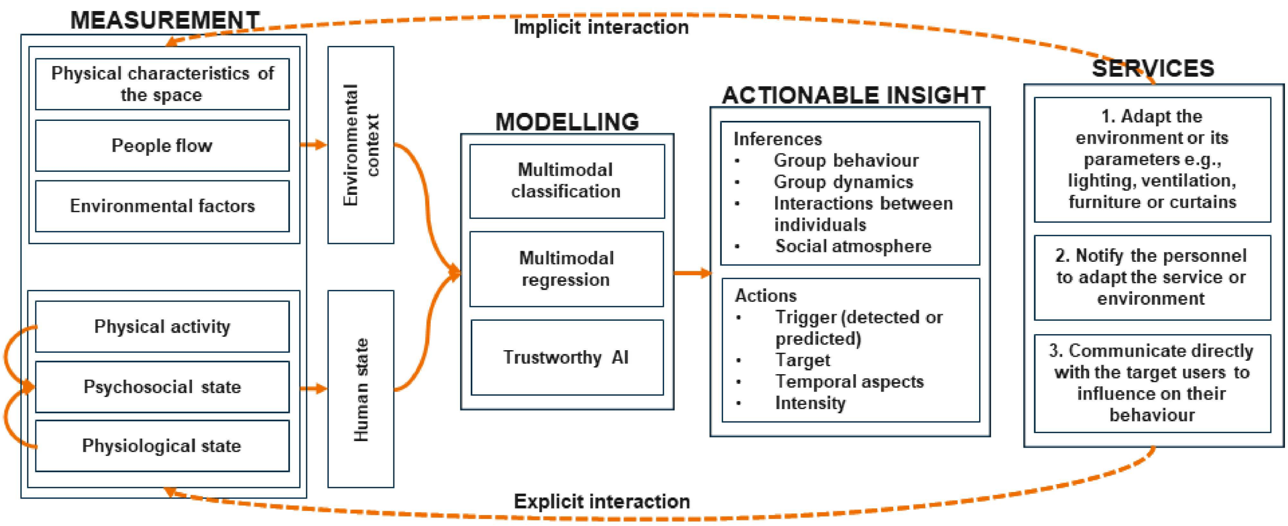

Figure 2. A behaviour and emotion recognition framework for emotion-aware services in physical spaces [6].

Camera analytics in the HIPE project involves a sophisticated pipeline that starts with the collection of raw video data from 2D, stereo (3D), or depth cameras.

The first step is the detection and tracking of people within the camera's field of view. Using advanced computer vision models, the system identifies human figures and constructs detailed skeleton models for each person. In the HIPE project, a 38-keypoint skeleton model is used, which provides precise information about the position and orientation of various body parts in both 2D and 3D space. Each detected person is assigned an anonymized identifier, allowing their movements and actions to be tracked over time without compromising privacy.

Once people are detected and tracked, the analytics pipeline extracts high-level behavioural features. One important aspect is the analysis of human-object interactions. The system uses state-of-the-art object detection models, such as Grounding-DINO, to identify objects in the environment (like laptops, pens, or cups) and to determine which objects are being interacted with by which person. This is achieved by mapping detected hand regions from the skeleton model to the bounding boxes of objects. The result is a detailed record of which objects each participant is handling at any given moment, providing insights into engagement and task participation.

Another key feature is the estimation of head pose for each participant. By analysing the orientation of the head (pitch, yaw, and roll), the system can infer where each person is looking and whether they are focused on the group, a particular speaker, or an object. This information is valuable for understanding attention, engagement, and group dynamics during collaborative activities.

The extracted features (e.g. trajectories, postures, head orientations, and object interactions) aggregated over time to build a comprehensive picture of individual and group behaviour. For example, the system can quantify how actively each participant is engaging with the environment, how synchronized the group is during a meeting, and how roles (such as presenter or listener) are distributed and enacted. These behavioural metrics can be used for further analysis, such as identifying patterns of collaboration, detecting periods of high or low engagement, and modelling the flow of interaction within the group.

All processing can be performed locally on edge devices, ensuring that raw video data does not leave the premises and privacy is maintained. The system is flexible, allowing users to select the level of abstraction depending on the application.

5.1.4 Situational awareness

WP3 also focused on creating situational awareness by integrating environmental data such as lighting, thermal conditions, audio-visual noise, and air quality with emotion and behaviour analysis. This holistic approach allowed the system to understand the context of behavioural activities and adapt service delivery accordingly. Algorithms for anomaly detection and context-aware analytics were developed to identify rare events or deviations in behaviour, supporting more responsive and adaptive environments. The integration of situational awareness tools enabled actionable insights that could be used to control and optimize the functionality of emotion-aware services in real time.

An important aspect of situational awareness is understanding both the absolute and relative locations of extracted information within the monitored environment. For example, when analysing head turns (direction of attention) among meeting participants, it is crucial to know each person's position in the scene as well as the relative positions of others. This spatial context allows for accurate interpretation of whom a participant may be focusing on.

To address this, the project developed a situational awareness layer that identifies the locations of key objects, such as people and provides tools for evaluating relationships between them. These relationships include, for instance, determining when one participant is directing attention toward another, or when a participant's hand is interacting with an object like a mobile phone.

The key objective of the HIPE project was to gain understanding of the situation for the selected use case contexts: In public transportation we demonstrated that it's possible to evaluate passenger comfort using camera sensors and in office environment we could successfully evaluate the quality of the meetings as well as identify tasks people were performing.

5.2 Emotion-aware service proof-of-concepts

The proof-of-concepts (PoCs) developed within the HIPE project serve as tangible demonstrations of how emotion-aware technologies can be integrated into real-world physical spaces. These initiatives were designed to validate the technical feasibility and added value of emotion-aware services in diverse environments such as public transportation, meeting rooms, and smart spaces. By collaborating with industry partners and piloting solutions in authentic settings, the project was able to assess not only the technological advancements such as multimodal sensing, AI-driven analytics, and real-time emotion detection but also the practical challenges related to privacy, usability, and regulatory compliance. The following section presents the main proof-of-concept cases, highlighting their objectives, implementation, and the insights gained regarding the deployment of emotion-aware services in everyday environments.

5.2.1 Comfort in Tram PoC

The Comfort in Tram proof-of-concept (PoC) was designed to showcase how emotion-aware technologies can enhance both passenger and operator experiences in public transportation, specifically within tram environments. The primary objective was to move beyond traditional safety and information systems by integrating real-time emotion and comfort analytics into the daily operation of trams. This approach aimed to create a more responsive, human-centric travel environment that could adapt to the collective mood and comfort of those on board.

Implementation involved a multi-partner collaboration, with Teleste providing the core passenger information and security video system, and Ambientia contributing situational awareness and data integration expertise. The technical setup of the final PoC implementation included RGB cameras, to collect emotion data. AI-driven analytics processed these data streams to recognize emotional states and generate a “tram comfort index.” This index was then used to dynamically adjust passenger information displays, alert tram drivers or control centres to emerging issues, and provide actionable insights via dashboards for operational staff. The system was designed with privacy in mind: video data was analysed in real time, with no continuous recording, emotion recognition was performed using anonymized data streams and the data was aggregated to group level.

The insights gained from the Comfort in Tram PoC were significant. Technically, the project demonstrated that real-time emotion recognition and comfort analytics could be integrated into existing public transport infrastructure, providing real-time feedback that improved both safety and the overall passenger experience. The comfort index enabled the system to modify information content and environmental cues in response to detected moods, such as increasing calming messages during periods of collective stress or alerting staff to potential disturbances. Feedback from tram drivers and operators highlighted the value of simple, actionable alerts over complex video feeds, supporting safer and more attentive driving. The project also revealed challenges: in the first technology experiments the biosignal data quality was affected by vibration and movement making the current seat foil sensor unusable in PoC implementation, and video analytics might face difficulties under changing lighting conditions. Importantly, the PoC underscored the need for careful attention to privacy and regulatory compliance, as well as the importance of transparent communication with passengers about how their data is used.

5.2.2 Mindful Meetings PoC

The Mindful Meetings proof-of-concept (PoC) was developed to address the common challenges of ineffective meetings by leveraging emotion-aware and activity-sensing technologies in real-world meeting environments. The primary objective was to create a smart meeting room that could sense, analyse, and respond to the dynamics of human interaction, with the goal of improving engagement, well-being, and productivity during meetings.

Implementation involved equipping meeting rooms with a range of sensors and analytics tools. These included seat foil sensors, RGB cameras, microphones, and environmental sensors to capture data on movement, speech activity, attention direction, and environmental conditions such as temperature and sound level. AI-driven analytics processed this multimodal data to generate real-time indicators of meeting engagement and synchrony such as how equally participants were involved, whether attention was focused, and if the group was working in harmony. The system provided feedback to participants and facilitators, highlighting when meetings were productive and when engagement was lacking. Importantly, the design prioritized privacy by focusing on anonymized, aggregate indicators rather than individual-level monitoring.

The insights gained from the Mindful Meetings PoC were substantial. The technology was able to reliably detect patterns of engagement and synchrony, distinguishing between productive and unproductive meeting moments. For example, the system could identify when attention waned, when one person dominated the conversation, or when the group was not collaborating effectively. This would allow for timely interventions, such as adjusting the environment or prompting a change in facilitation style, to improve meeting outcomes. User feedback indicated that the indicators aligned well with subjective experiences of meeting quality. The PoC also highlighted the importance of transparency and user trust, as participants would value clear communication about what data was being collected and how it was used. Overall, the Mindful Meetings PoC demonstrated the potential for emotion-aware, sensor-driven environments to transform meetings into more effective, engaging, and human-centric experiences, while also surfacing important considerations around privacy, usability, and organizational adoption.

The Mindful Meetings PoC demonstrated that a well-instrumented meeting environment can provide real-time indicators of group activity and engagement, supporting more effective and responsive facilitation. Among the simplest and most actionable metrics, noise level could be a reliable indicator of the range and intensity of activity in the room, a “low-hanging fruit” for immediate feedback and intervention. The AI-driven analytics were particularly efficient at detecting and quantifying straightforward aspects such as the number of people present, the use of devices, and general movement patterns. However, the technology was less effective at reliably interpreting emotional states, especially when relying on sparsely sampled still images. This limitation highlights the ongoing challenge of emotion recognition in dynamic, real-world settings. Additionally, the project observed that the cost of AI solutions can fluctuate significantly: technologies that were previously considered prohibitively expensive can rapidly become accessible as AI capabilities expand and new tools (such as advanced prompting techniques) become available. This rapid evolution in both affordability and functionality underscores the importance of continuous evaluation and adaptation when deploying AI-powered solutions in meeting environments.

5.3 Regulatory perspective on HIPE

Emotion-aware services process “emotional data”, which includes biometric and identifiable human-based data, such as facial expressions, which can uniquely identify individuals. These data are highly sensitive, and their use in AI-driven systems raises significant concerns about privacy, trust, and the unforeseen implications of such technologies. Ensuring that all ecosystem actors are well-informed and vigilant is essential to harness the benefits of emotion-aware technologies while minimizing risks. The HIPE project team studied the ethical and legal aspects of emotion-aware technologies from different perspectives. A key outcome was the *HIPE Legal and ethical guidelines* [1] which is summarized below.

5.3.1 Legal and ethical guidelines for the development of emotion-aware services

Research involving emotion-aware technologies must adhere to strict ethical standards, particularly when human participants are involved. Participants must be given clear and comprehensive information about the inherent aims and risks as well as the processed data and the data processing methods of the research, in a language they understand. Their participation must be voluntary, and they shall retain the right to withdraw at any time without negative consequences. The dignity and autonomy of each participant must be respected, and the research must not cause them any harm. When interventions in physical integrity are involved, ethical review is required to ensure compliance with national and institutional standards.

The legal landscape for emotion-aware services is shaped by several key regulations. The General Data Protection Regulation (GDPR) mandates that the processing of emotional data is lawful only with explicit, informed consent for specific purposes. The principles of lawfulness, fairness, transparency, purpose limitation, data minimization, storage limitation, integrity, confidentiality, security, accuracy, and accountability are central to all data processing activities. Only necessary data should be collected, and personal data must be erased when it is no longer needed. Personal data must not be disclosed in research results or made publicly available.

The Artificial Intelligence Act (AIA) introduces a human-centric approach to AI development and deployment, emphasizing respect for human dignity, freedom, democracy, and fundamental rights. The AIA applies a risk-based regulatory framework, with stricter requirements for high-risk AI systems such as remote biometric identification or emotion recognition. Certain applications, including real-time biometric identification in public spaces and emotion recognition in law enforcement, workplaces, and educational institutions, are prohibited. The open-ended and multi-interpretable definitions, enhanced by the EU Commission Guidelines on interpretation of Article 5, can result in practical problems for innovations. Innovative AI systems may be tested in controlled environments (regulatory sandboxes), but legal requirements must be proactively addressed.

The Council of Europe regulations further reinforce the importance of human dignity, autonomy, and control over personal data. Individuals must not be subject to significant decisions based solely on automated processing without human review.

Liability regulations play a crucial role in the deployment of emotion-aware services, particularly as these technologies interact with sensitive personal data and may influence human behaviour. The regulatory environment recognizes that traditional liability rules may not sufficiently cover the complexities of AI-driven decision-making, especially when errors or malfunctions occur. As a result, there is a push for clearer definitions and directives that allocate responsibility among developers, operators, and users of emotion-aware technologies. However, efforts to harmonise liability rules for AI-related harm at the EU level have failed. The proposal for an AI Liability Directive (AILD) was withdrawn in February 2025.

Intellectual property rights (IPR) are a critical aspect to incentivise development and deployment of emotion-aware services in physical spaces, where innovative technologies demand high investments, but also imply several risks in terms of economic return due to the intersection with sensitive personal data and complex regulatory frameworks. In collaborative projects like HIPE, consortium agreements and data management plans establish clear provisions for the ownership, use, and protection of research outputs. These agreements are designed to ensure that all partners have equitable access to the intellectual property generated, while also safeguarding the interests of creators and users. However, the regulatory environment for emotion-aware technologies tends to emphasize risk mitigation and compliance, sometimes at the expense of positive legal incentives that could encourage further innovation. [2]

The development and deployment of emotion-aware services must be guided by fundamental ethical principles. Fairness, justice, and equality require that all individuals are treated with respect, regardless of their background. Human-centricity and user-centricity emphasize the empowerment of users, ensuring they are informed and able to make choices about their data (e.g. data sovereignty) and participation. Sustainability and inclusiveness are vital, promoting operations that are economically, environmentally, and socially responsible, and fostering diversity within development teams and applications.

Transparency and effective communication are crucial for building trust, both within the project and with research participants and the public. Information must be clear, accessible, and understandable. Security is paramount, with robust measures in place to protect data and respond to breaches. Collaborative working ensures integrity, protection of intellectual property, and responsible publication of research results. Finally, continuous improvement is encouraged, with ethical principles evolving based on feedback and ongoing evaluation.

Emotion-aware services in physical spaces must navigate a complex landscape of legal, regulatory, and ethical requirements. The HIPE Legal and Ethical guidelines emphasize the need for explicit consent, transparency, data minimization, and robust security measures. They also highlight the importance of fairness, human-centricity, and continuous ethical reflection. Compliance with GDPR, the AI Act, and Council of Europe regulations is paramount. Ultimately, the responsible development and deployment of emotion-aware technologies depend on a deep commitment to ethical principles and legal compliance.

5.3.2 Regulatory gaps: Divergent legal definitions and their impact on emotion-aware services

A regulatory landscape dominated by preventive, risk-based approaches, such as those found in the GDPR and the AI Act, tends to prioritize compliance, risk mitigation, and the avoidance of harm, often at the expense of fostering innovation in emotion-aware services. While these frameworks are essential for protecting fundamental rights and ensuring ethical use of sensitive emotional data, they can inadvertently create an environment where legal obligations ("sticks") outweigh positive legal incentives ("carrots") for technological advancement. This imbalance may discourage investment and experimentation, as innovators face uncertainty as to what exactly their obligations are and what the consequences of non-compliance with these obligations are - without clear rewards or support for responsible development. The scientific literature highlights that, in the context of emotional AI, there is a pressing need for regulatory models that not only safeguard the rights of individuals but also actively encourage innovation such as through intellectual property rights, targeted incentives, and clearer pathways for commercialization. Without such positive incentives, the regulatory focus on risk can stifle the emergence of new solutions and limit the societal benefits that emotion-aware technologies could offer. [2]

The current regulatory landscape for emotion-aware services is marked by a significant lack of harmonization in liability regulations across jurisdictions. Despite the increasing deployment of AI-driven emotion recognition technologies in physical spaces, there is no unified legal framework that clearly defines who is responsible when these systems cause harm or malfunction. As mentioned above, efforts to create a harmonized liability directive at the European level have so far failed, leaving a patchwork of national rules and contractual arrangements. This fragmentation leads to uncertainty for developers, operators, and users of emotion-aware services, as liability may be interpreted differently depending on the country or context. The absence of clear, harmonized rules complicates the allocation of responsibility, especially in cases involving cross-border data flows or collaborative innovation. As highlighted in recent legal scholarship, this regulatory gap not only increases legal risk and compliance costs but may also stifle innovation, as organizations hesitate to invest in new technologies without clear guidance on liability exposure. Addressing this lack of harmonization is essential for building trust, ensuring accountability, and supporting the responsible development and deployment of emotion-aware services in society. [3][4]

A significant challenge in the regulation of emotion-aware services and AI technologies is the lack of harmonization in the interpretation of key legal definitions. For example, the AI Act, while aiming to provide a unified regulatory framework, is often criticized for its vagueness. This vagueness leads to inconsistent interpretations across different jurisdictions and stakeholders, making it difficult for organizations to understand their obligations and for regulators to enforce compliance uniformly. The absence of clear, universally accepted definitions creates uncertainty, which can hinder innovation and complicate the deployment of AI solutions in physical spaces. As highlighted in policy briefs and expert commentaries, this ambiguity not only affects legal certainty but also undermines trust in regulatory processes, as organizations and individuals may interpret the same provisions in divergent ways. [5]

The project findings underscore also that the current regulatory frameworks governing emotion-aware services (such as the GDPR and the AI Act) are often characterized by vague definitions and intricate requirements, making them difficult for non-experts to understand and navigate. This complexity creates a significant barrier to transparency, as individuals and organizations without specialized legal or technical knowledge may struggle to comprehend their rights, obligations, and the implications of deploying or interacting with emotion-aware technologies. As a result, laypeople are frequently left without clear guidance or accessible explanations regarding how their emotional data is processed, what safeguards are in place, or how they can exercise control over their information. In other words, instead of being user-centric, the decision-making framework is rather centralised and top-down. This lack of clarity and education, coupled with a sense of being left out from the process and not being able to take informed decisions, not only undermines public trust but also hampers informed participation and oversight, ultimately limiting the societal benefits, impact and acceptance of the innovations in this field. Addressing these challenges requires not only clearer and more accessible regulatory language but also dedicated efforts to educate and engage the public about the rights, risks, and responsibilities associated with emotion-aware services. [4]

5.4 Business insights on emotion-awareness technologies

Emotion-aware services in physical spaces represent a rapidly emerging market with significant business potential across sectors such as transportation, office environments, retail, and public venues. The emotion AI market is projected to grow from $2.74 billion in 2024 to $9.01 billion by 2030, at a CAGR of 21.9% during the forecast period.[1] The global affective computing market size was estimated at $62.53 billion in 2023 and is projected to reach $388.28 billion by 2030, growing at a CAGR of 30.6% from 2024 to 2030.[2] Rapid advancements in AI, machine learning (ML), and sensor technologies, coupled with an increased emphasis on offering an enhanced user experience, contribute to the market growth. This growth is closely linked to the expanding Smart Buildings Market, which is forecasted to exceed $548 billion by 2032[3]. As organizations seek to enhance user experience, safety, and operational efficiency, the demand for technologies that can sense, interpret, and respond to human emotions and behaviors is growing. Poor emotional management in the workplace alone costs the global economy an estimated $8.8 trillion annually in lost productivity.[4]

[1] https://www.marketsandmarkets.com/Market-Reports/emotion-ai-market-134111673.html (Retrieved 17.11.2025)
[2] https://www.grandviewresearch.com/industry-analysis/affective-computing-market (Retrieved 17.11.2025)
[3] https://www.fortunebusinessinsights.com/industry-reports/smart-building-market-101198 (Retrieved 17.11.2025)
[4] https://www.gallup.com/workplace/393497/world-trillion-workplace-problem.aspx (Retrieved 17.11.2025)

The deployment of multimodal sensor networks, advanced AI-driven analytics, and real-time data fusion enables the creation of adaptive environments, which are part of smart buildings. For example, the market for Smart Furniture, including adjustable and connected office pods utilized in HIPE, is projected to grow by nearly 15% annually reaching $486.2 million by 2030.[5] Integrating emotion AI with Smart Lighting Systems allows for subtle environmental adjustments. The Smart Lighting market is projected to reach $72.35 billion by 2030.[6] Similarly, the global market for Intelligent Transportation Systems (ITS) is set to reach over $65 billion by 2032[7], driven by the need for advanced Passenger Information Systems (PIS) and enhanced safety features. In public transport, Emotion AI enables PIS to move beyond static data, offering context-aware safety alerts and mood-optimizing lighting and audio on board—critical for the future of automated public transport, where AI must monitor and manage passenger stress or distress to ensure reliable autonomous operation.

These innovations open new avenues for service differentiation and value creation, allowing companies to offer personalized, responsive solutions that meet evolving customer expectations. However, realizing this potential requires overcoming technical challenges related to data integration, privacy, and regulatory compliance (e.g., GDPR), as well as developing scalable business models. As the cost and accessibility of AI solutions continue to improve, and as regulatory frameworks evolve (e.g., the EU AI Act), the market for emotion-aware services is poised for expansion, offering opportunities for both established players and innovative newcomers.

In HIPE project, the HIPE Perceptor was envisioned as an intelligent, modular platform designed to enable development of emotion-aware physical spaces able to sense, interpret, and respond to human activity and emotional states. The core idea is to leverage a combination of multimodal sensors such as cameras, seat foil sensors and environmental sensors alongside advanced AI analytics to create a real-time “perception layer” for smart environments. This enables adaptive services that can respond to the collective mood, engagement, and comfort of occupants, supporting applications in public transport, meeting rooms, and other shared spaces.

The HIPE Perceptor concept was assessed through proof-of-concept demonstrations in real-world environments, such as public transport and meeting rooms, where its ability to sense, interpret, and respond to human activity and emotional states was tested. The evaluation focused on the accuracy and robustness of emotion recognition, the adaptability of the system to different physical and usage contexts, and the effectiveness of privacy-preserving measures. Feedback from developers and operational staff, as well as technical performance data, informed the ongoing refinement of both the sensing technologies and the underlying algorithms, highlighting strengths and limitations in practical deployment.

Based on the experiments it is clear that HIPE Perceptor idea faces several limitations. The accuracy of emotion recognition is constrained by the quality and diversity of sensor data, with challenges arising from sparse sampling, variable lighting conditions, and privacy-preserving requirements that limit continuous data collection and usage. Additionally, the system’s ability to generalize across different environments and usage contexts is restricted, as behavioral norms and expectations can vary widely. Technical hurdles such as data transfer capacity, edge computing constraints, and compliance with GDPR and other privacy regulations further complicate deployment. These limitations highlight the need for ongoing refinement of both the sensing technologies and the underlying algorithms to ensure reliable, ethical, and user-accepted emotion-aware services in real-world settings.

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[5] https://www.grandviewresearch.com/industry-analysis/smart-furniture-market-report (Retrieved 17.11.2025)
[6] https://www.grandviewresearch.com/industry-analysis/global-smart-lighting-market (Retrieved 17.11.2025)
[7] https://www.fortunebusinessinsights.com/intelligent-transportation-system-market-102065 (Retrieved 17.11.2025)

6. Dissemination and exploitation of results

6.1 Dissemination activities

The dissemination activities for the HIPE project were multifaceted, aiming to maximize visibility and impact across scientific, industry, and public domains. The project maintained a dedicated website (www.hipe-project.com) and issued press releases to highlight key milestones, such as the service PoCs. Scientific publications were produced in leading journals and conference proceedings, covering topics from legal incentives in emotional AI to technical frameworks for emotion recognition in physical spaces. The team actively participated in presentations and events, including conferences, webinars, radio interviews, and science communication forums, fostering dialogue with both academic and industry audiences. The collaborative research exchange between VTT and the University of Turin advanced personalized stress and cognitive load detection models. Overall, these dissemination efforts ensured that the project's findings, technological innovations, and regulatory insights reached a broad spectrum of stakeholders, supporting further research, commercialization, and informed public debate on emotion-aware technologies. A comprehensive list of dissemination activities can be found in Appendix of this report.

6.2 Exploitation plans

The HIPE project partners have developed a range of innovative technologies, research methods, and business concepts throughout the project. This section outlines how each consortium member intends to exploit the results, whether through commercial deployment, further scientific research, or integration into new products and services. By leveraging the project's outcomes, the partners aim to maximize the impact of HIPE across industry, academia, and society.

At this stage, **Framery** has no active plans to incorporate the results into Framery's product and service offering. Instead, the project has provided Framery with valuable, R&D-relevant information on what is and what is not possible with state-of-the-art technology, especially with respect to sensoring and processing algorithms, to inform future R&D work and offering roadmapping.

During HIPE project **Helvar** ran number of research initiatives on the sensors, first mile transmission in premises, to cloud, and finally to customer insight. For these we plan to exploit the results as follows:

- **Sensors:** during project several sensors and topologies were tested. For this we have plans to expand the offering we currently have with current hardware for new insights, as well as continue sensor development to some of the areas researched.
- **On-premises wireless mesh:** As we currently deploy wireless mesh networks, we already have capability to commercially deploy new services. On top of that, the design work for future transport is taking HIPE research findings into use, for higher throughput solution.
- **Cloud:** Cloud architecture has the smallest footprint that enjoyed benefits from HIPE, namely because it already was quite capable to process any data thrown at its general direction. However, during HIPE a lightweight "Future Insights" service for rapid prototyping and validation was realized, with it, we are planning on covering more area with advanced insights.
- **Visualizations - Insights:** During the HIPE project we released number of insights onto Future Insights -platform. We plan on continuing this track to release insights and transform some of the existing into commercial services.

In short, Helvar is transforming features discovered in HIPE to our next generation offering and transforming proof-of-concept insights to commercial grade offering for wide deployment.

Participation in the HIPE project has enabled **Teleste** to acquire advanced know-how in emotional analytics and related technologies, which Teleste has already been leveraged in ongoing research initiatives. Building on this foundation, Teleste's strategic goal is to integrate emotion recognition into its CCTV surveillance and Passenger Information Systems, creating innovative solutions that enhance safety, situational awareness, and passenger experience.

In the short term, Teleste will focus on refining real-time emotion detection algorithms and validating their performance in controlled environments. Mid-term actions include pilot deployments with transportation operators to assess operational benefits, gather user feedback, and ensure compliance with privacy and ethical standards. Importantly, Teleste has also gained significant expertise in GDPR requirements and emerging regulations such as the EU AI Act. This knowledge will be applied not only to future emotion recognition developments but also across other areas of Teleste's business, ensuring robust data protection and regulatory compliance.

Long-term, Teleste aims to commercialize emotion recognition as a premium feature within its product portfolio, offering transport operators tools for improved crowd management, stress detection, and personalized passenger information. By leveraging HIPE outcomes and regulatory insights, Teleste will deliver differentiated offerings that combine security, safety, and customer engagement. This approach aligns with global trends toward intelligent transportation systems and reinforces Teleste's position as a technology leader committed to innovation and responsible AI.

The **University of Lapland** will leverage the multidisciplinary research results, methods, and collaborations stemming from HIPE for new national (e.g., the Research Council of Finland and Business Finland) and international (e.g., Horizon Europe) research projects related to the regulation of artificial intelligence (AI) in general and emotional AI in particular. The unique technological and business implications of regulation, as learned during HIPE from theoretical and practical perspectives, opened new avenues of research on the role of law and ethics in emotional AI and other emerging sensitive technologies. While it is increasingly evident that Finland and Europe need to regulate AI in order to be competitive global leaders, the question of ***how*** to regulate remains largely unaddressed. The knowledge gained and produced during HIPE gives Finnish researchers a competitive advantage when contributing to these global discussions.

VTT plans to leverage the outcomes of the HIPE project through several strategic avenues. First, the research findings and technological advancements such as multimodal sensing environments, AI-driven analytics, and privacy-preserving data pipelines will be further developed into scalable solutions for human-aware services in smart environments. VTT will pursue licensing opportunities for key technologies created during HIPE, enabling commercial partners to integrate these innovations into their own products and services. Additionally, VTT has already used and will continue to use the project's results as a foundation for new research initiatives, both nationally and internationally, focusing on human-aware physical spaces in different domains and the related technologies. These new projects will build on the multidisciplinary collaborations established in HIPE, fostering ongoing innovation and knowledge exchange.

7. Discussion and conclusions

The HIPE project has demonstrated the technical feasibility and practical value of emotion-aware services in physical spaces, leveraging advances in multimodal sensing, AI-driven analytics, and collaborative system design. The proof-of-concept implementations in public transport and meeting environments have shown that real-time emotion and activity indicators can enhance user experience, safety, and operational efficiency. These results highlight the potential for adaptive environments that respond to collective mood and engagement, supporting more human-centric and responsive services.

However, the project also surfaced several challenges that must be addressed for broader adoption. Technical limitations persist, particularly in emotion recognition accuracy, which is constrained by sensor quality, sparse sampling, and privacy-preserving requirements. The integration of diverse sensor types and the need for scalable data fusion pipelines require ongoing refinement. Data management issues such as transfer capacity, edge computing constraints, and compliance with GDPR add further complexity, especially when operating across different geographical areas. The lack of harmonization in regulatory definitions and liability frameworks creates uncertainty for developers and users, while the focus on data identification in privacy regulation risks making compliance impractical for future AI systems.

From a business perspective, the market for emotion-aware services is poised for growth, driven by increasing demand for personalized, adaptive environments in sectors like transportation, offices, and retail. Yet, realizing this potential depends on overcoming technical, regulatory, and cultural barriers, as well as developing sustainable business models. The HIPE Perceptor concept, while promising, illustrates the need for ongoing innovation in sensing technologies, algorithms, and privacy solutions. Ultimately, the responsible deployment of emotion-aware services will require a balance between technological capability, ethical principles, and legal compliance, supported by clear regulatory guidance and positive incentives for innovation.

8. Summary

The HIPE project has demonstrated the technical feasibility and practical value of emotion-aware services in physical spaces, leveraging advances in multimodal sensing, AI-driven analytics, and collaborative system design. Proof-of-concept implementations in public transport and meeting environments have shown that real-time emotion, behaviour and activity indicators based on group-level measurements can enhance user experience, safety, and operational efficiency. These results highlight the potential for adaptive environments that respond to collective mood and engagement, supporting more human-centric and responsive services. However, several challenges remain for broader adoption, including technical limitations in emotion recognition accuracy, integration of diverse sensor types, scalable data fusion pipelines, and compliance with privacy regulations such as GDPR. The lack of harmonization in regulatory definitions and liability frameworks creates uncertainty for developers and users, while the focus on data identification in privacy regulation risks making compliance impractical for future AI systems. From a business perspective, the market for emotion-aware services is poised for growth, driven by increasing demand for personalized, adaptive environments in sectors like transportation, offices, and retail. Realizing this potential depends on overcoming technical, regulatory, and cultural barriers, as well as developing sustainable business models. The HIPE Perceptor concept, while promising, illustrates the need for ongoing innovation in sensing technologies, algorithms, and privacy solutions. Ultimately, the responsible deployment of emotion-aware services will require a balance between technological capability, ethical principles, and legal compliance, supported by clear regulatory guidance and positive incentives for innovation.

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[2] Rosa Maria Ballardini, Rob van den Hoven van Genderen, Tomi Nokelainen, Legal incentives for innovations in the emotional AI domain: a carrot and stick approach?, *Journal of Intellectual Property Law & Practice*, Volume 19, Issue 8, August 2024, Pages 658–667, https://doi.org/10.1093/jiplp/jpae041

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[4] Schütte, B., van den Hoven van Genderen, R., Ballardini, R., Vesala, J., & Drake, A. (2024). HIPE Project Policy Brief: Emotionally Intelligent AI in the Workplace – Risks, Benefits, Accountability. *Liikejuridiikka*, (2/2024), 108-114. https://www-edilex-fi.ezproxy.ulapland.fi/liikejuridiikka/1000990005

[5] van den Hoven van Genderen, R., & Ballardini, R. (2024). AI and Emotional data between the Scylla and Charybdis of European Regulation. *Jusletter IT*, (15.2.2024 IRIS), 57-66. https://doi.org/10.38023/aa115617-978f-4d5a-93a7-5b9f16005cf0

[6] Järvinen, S., Kallio, J., Peltola, J., & Mäkelä, S. M. (2024). A behavior and emotion recognition framework for emotion-aware services in physical spaces. In *21st International Conference on Content-Based Multimedia Indexing, CBMI 2024 - Proceedings* IEEE Institute of Electrical and Electronic Engineers. https://doi.org/10.1109/CBMI62980.2024.10859231

Appendix

Dissemination activities

Website: www.hipe-project.com

Press releases:

AI-powered tram senses mood on board and prevents disturbances – new technology reshapes passenger experience, 28.5.2025, https://www.vttresearch.com/en/news-and-ideas/ai-powered-tram-senses-mood-board-and-prevents-disturbances-new-technology-reshapes

Meeting room senses activity – VTT technology identifies when meetings aren't working, 28.8.2025, https://www.vttresearch.com/en/news-and-ideas/meeting-room-senses-activity-vtt-technology-identifies-when-meetings-arent-working

Scientific publications:

Ballardini, R., van den Hoven van Genderen, R., & Nokelainen, T. (2024). Legal Incentives for Innovations in the Emotional AI Domain: A Carrot and Stick Approach? *Journal of Intellectual Property Law and Practice*, *19*(8), 658-667. https://doi.org/10.1093/jiplp/jpae041

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Järvinen, S., Kallio, J., Peltola, J., & Mäkelä, S. M. (2024). A behavior and emotion recognition framework for emotion-aware services in physical spaces. In *21st International Conference on Content-Based Multimedia Indexing, CBMI 2024 - Proceedings* IEEE Institute of Electrical and Electronic Engineers. https://doi.org/10.1109/CBMI62980.2024.10859231

Ballardini, R., van den Hoven van Genderen, R., & Järvinen, S. (Eds.) (2025). *Emotional Data Applications and Regulation of Artificial Intelligence in Society*. Springer. Law, Governance and Technology Series No. 69 https://doi.org/10.1007/978-3-031-80111-2

Ballardini, R., & Pitkänen, O. (2025). Fair and sustainable data governance for responsible uses of emotional data. In R. Ballardini, S. Järvinen, & R. van den Hoven van Genderen (Eds.), *Emotional data applications and regulation of Artificial Intelligence in society* (pp. 201-219). Springer. https://doi.org/10.1007/978-3-031-80111-2_12

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Tervonen, J. (2025). Personalized multiclass stress and cognitive load detection. In *Proceedings of the Discovery Science Late Breaking Contributions 2024 (DS-LB 2024) co-located with 27th International Conference Discovery Science 2024 (DS 2024)* CEUR-WS. https://ceur-ws.org/Vol-3928/paper_68.pdf

Kallio, J., Liikka, J., Mäkelä, S-M., Kinnula, A. & Vildjiounaite, E. (2025). Understanding indoor context in an office environment: An empirical study on air stuffiness perception. In the proceedings 2025 International Conference on Content-Based Multimedia Indexing (CBMI).

Submitted for evaluation:

Kinnula A., Vita, J. & Kallio, J. Integrating ethics support to the design process – a case of commercial product and service innovation project, *Design Studies*, Elsevier.

Tervonen, Amparore, Botta, Närväinen, Pettersson, Mäntyjärvi. Personalizing Cognitive State Detection with Minimal Person-Dependent Data. *Transactions on Affective Computing.*

Other publications:

Ballardini, R., van den Hoven van Genderen, R. (2022). 'From Lapland with Law ': Transparency and sharing requirements for data in the EU – stimulating or killing innovations? Blogpost in From Lapland with Law blog

A news article on "European Digital Identity (eID) Wallet: a Paradigm Shift for Digital Identity in Europe – Start for a European Social Credit System?" by van den Hoven van Genderen to Data Cybersecurity and Privacy (February 2023)[8]

Schütte, B., van den Hoven van Genderen, R., Ballardini, R., Vesala, J., & Drake, A. (2024). HIPE Project Policy Brief: Emotionally Intelligent AI in the Workplace – Risks, Benefits, Accountability. *Liikejuridiikka*, (2/2024), 108-114. https://www.edilex.fi/liikejuridiikka/1000990005

Väre, J. (2025, June 26). From Sci-Fi to Reality: How Emotional Intelligence Found Its Way into a Tram. Teleste. https://www.teleste.com/news-and-insights/articles-and-blogs/vsi/blog/from-sci-fi-to-reality-how-emotional-intelligence-found-its-way-into-a-tram/

Presentations and events:

- HIPE presentation in "Augmenting humans with AI-driven knowledge" event, October 2022, Espoo, Finland, Johannes Peltola, VTT
- the FARIA network[9] webinar in March 2023, University of Lapland
- A radio interview by van den Hoven van Genderen on "On ban on Artificial intelligence" (31 March 2023)[10]
- Organization of the conference "Ethical and Legal Aspects on Human-Technology Interoperability and AI Processing of Emotional Data" on 6 June 2023, University of Lapland
- Ballardini and van den Hoven van Genderen participated as a panelist and a speaker respectively to the Science Night LIVE event[11] organized at Heureka, Vantaa
- Presentation by Béatrice Schütte on liability and AI in an informal meeting with resident researchers at VU Amsterdam held in June 2023

[8] https://www.dcsp.nl/art/90-5576_European-Digital-Identity-eID-Wallet-a-Paradigm-Shift-for-Digital-Identity-in-Europe-Start-for-European-Social-Credit-System
[9] https://www.faria.network/
[10] https://www.nporadio1.nl/nieuws/economie/463a65ed-27a0-468e-9f0e-67b4ee5c73b4/oproep-om-ai-ontwikkelingen-te-pauzeren-onzin-en-gebaseerd-op-angst
[11] https://www.sciencenightlive.com/

- HIPE project pitch in the Nordic Conference on Law and Information Technology, October 2023, Rovaniemi, Finland, Sari Järvinen, VTT
- HIPE Final event October.2025, Espoo: Sari Järvinen (VTT), Johannes Peltola (VTT), Rob van den Hoven van Genderen (ULap), Béatrice Schütte (ULap), Rosa Ballardini (ULap), Henri Juslen (Helvar), Tiia Järvenpää (Teleste), Tuuli Aalto (Ambientia)
- Organization of a Special Session on “Multimodal Data Analysis for Understanding of Human Behaviour, Emotions and their Reasons” for the 21st International Conference on Content-based Multimedia Indexing (https://cbmi2024.org/) organized in September 2024.
    - Special session with 8 papers and a panel discussion
- Happy future mobility, 19.11.2025 klo 8-10, VTT Slush Science breakfast, Espoo, Eetu Pilli-Sihvola (VTT)
- Kohti älykkäämpiä neuvottelutiloja – mittausteknologioilla objektiivista tietoa päätöksenteon tueksi, 24.11.2025, Pohjois-Suomen Rakennusklusteri ry - Terveet tilat, Oulu, Johanna Kallio (VTT)

Research exchange

A research exchange between VTT and the University of Turin (1.9.-30.11.2024) focused on personalizing cognitive state detection models for stress and cognitive load using minimal person-dependent data. The goal was to enable accurate, individualized detection with just a short baseline measurement from each user, rather than requiring extensive personal data. This is important for practical applications where collecting large amounts of data from every new user is not feasible. Two methods, continual normalization and baseline calibration, outperformed non-personalized models, especially in multi-class tasks. These results support efficient, individualized detection with limited data and clarify trade-offs between model complexity and accuracy. Final results have been submitted for publication in IEEE Transactions on Affective Computing.