



Mobile–neural friendly architecture for limiting exposure to traumatic scenes

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Abstract

Mobile devices play a key role in developing mental health focused applications for individuals. The presented research proposes using mobile devices to limit the occurrence of depression in disabled individuals. It proposes a novel two stage solution that limits depression in disabled subscribers. The solution is integrated in a headband. Disabled subscribers have been considered because of their limited ability (or inability) to demonstrate motor skills enabling them to avoid trauma triggering scenarios. The research also examines how the proposed mechanism influences an individual's identity. This is because existing solution utilize an invasive approach while the proposed solution is non-invasive. Analysis shows that the proposed mechanism preserves individual identity by 74.2%–99.3% on average.

Keywords Mobile devices · Disability integration · Wireless networks · Human health · Consciousness · Intelligence

1 Introduction

Artificial intelligence (AI) is integral in providing principles enabling evolutionary algorithms design. AI techniques have been deployed in computing and communication networks (Swayamsiddha 2020; Singh et al. 2021; Raychaudhuri and De 2020; Dressler 2009; Dressler and Akan 2010; Safitri et al. 2019). The prevailing perspective is that biological systems and models host a considerable number of computational principles. These computational principles can be used to design techniques suitable for addressing different challenges.

The focus of the prevailing perspective is to create synthetic intelligence from these techniques. However, this

approach does not enable the acquisition of an improved understanding of how the brain functions which is an important goal of artificial intelligence (Winston and Minsky 2016). The existing approach focuses on viewing the biological system as a substrate for intelligent and sophisticated mechanisms. An equally important objective is improving the understanding of the how the brain functions (Herculano-Houzel 2012). However, this objective has received a lesser focus. Research also aims to enhance the understanding of the brain's functions via the use of insights from other domains such as systems science (Badcock 2019), network architecture and psychiatry (Bassett and Sporns 2017). This paper considers the notion that insights from psychiatry can influence wireless communications and the design of future intelligent solutions.

The discussion here addresses the challenge of ensuring that disabled individuals and subscribers are able to avoid traumatic scenarios that trigger depression. The proposed solution fits within the future goal of accommodating disabled individuals in future networking (Johansson et al. 2021; Scanlan 2021). These challenges should be addressed in the context of evolving mobile communications. The discussion in this paper presents solutions describing applications of neural technologies in the evolution of future networks.

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Research contribution: The main contribution is the design of a health focused solution for individuals using devices for information access. The presented research proposes a paradigm and architecture that enables the user of computing devices to avoid contexts and scenarios that cause mental health related concerns. The discussion in the presented research contributes to research by developing a solution that limits the occurrence of depression and encounter with negative trauma triggering scenarios in subscribers that use computing and networking devices to access data and content. The focus of the presented research is the description of a novel computing-based method to address the occurrence of mental health challenge. The concerned mental health challenge arises when an individual is in a traumatic scenario, or context. It is recognized that memory modification techniques and technologies have emerged due to advances in clinical neuroscience. However, the technological advances are invasive in context with significant challenges in altering the consciousness as a risk after procedure execution. The presented research proposes a computing-based solution. The proposed computing-based solution limits individual exposure to scenarios and contexts that trigger negative mental health outcomes. It is non-invasive with reduced risk on altering individual consciousness. The details of the contributions in the presented research are:

- (1) First, the paper proposes the distributed mind and consciousness paradigm that uses perspectives from transcultural psychiatry, and the integrated information theory of consciousness. In the proposed paradigm, neurons are considered the basic components of the perception of consciousness and human capability. The proposed paradigm serves as the basis for developing the data driven non-erasure traumatic memory for addressing depression and grief. It also serves as the basis for the design of the data driven non-memory grief erasure and hair-based data driven system.
- (2) Second, the paper proposes a mobile device assisted non-memory erasure grief therapy. The proposed therapy that enable individuals to overcome the effects of traumatic memories. The individuals being considered are those with partial but not total impairments of the auditory and visual senses. The proposed non-memory erasure grief therapy differs from existing work in addressing traumatic memories (Cheng et al 2020; Liivoja and Kroes 2020, Adamczyte and Zawadzki 2020; Hu et al. 2017, Han et al. 2020). Existing work has considered identifying and deleting the painful memories and has two drawbacks. The first is that it is assumed that the neuronal wiring and synapses associated with traumatic event are non-beneficial. Second, the deletion of painful memories is individual specific and not easily replicated for multiple individuals who have witnessed a traumatic event. The non-memory erasure grief therapy presents an approach to overcome these drawbacks. It presents a large scale and data driven solution that is integrated with future mobile phone and user entity.
- (3) In addition, the paper formulates the consciousness validity index (CVI). The CVI is formulated for the proposed mobile integrated and non-memory erasure technology. It is proposed to quantify how the integration of neural technologies influences a person's identity due to execution of brain invasive procedures. The CVI is formulated for the existing approach of using brain implants. It is also formulated for the proposed data driven non-memory erasure mobile integrated grief approach. The performance benefit is investigated via simulation for the existing approach and proposed approach. This is done for the task of memory modification.

The presented research is deemed important because of the increased activity of neural technology start-ups such as Neuroable, Halo Neuroscience and Thync. In addition, the discussion in the paper presents a neuro-computational perspective to the presented solutions.

The discussion in the paper is structured as: Sect. 2 and Sect. 3 discuss the existing work and problem, respectively. Section 4 describes the proposed solution. Section 5 concludes the paper.

2 Background work

The discussion in this section presents the background work related to the presented research. It has two sections. These are Sect. 2.1, Sect. 2.2, Sect. 2.3, and Sect. 2.4. Section 2.1 examines existing work in the aspect of using memory modification and related technologies for addressing trauma arising from painful memories. Section 2.2 describes relations between emerging mobile technologies and neural applications. The discussion in Sect. 2.3 presents the background work with relation to the area of the internet of senses. In addition, the discussion in Sect. 2.4 describes the existing work in the aspect of artificial intelligence with focus on the future role in mental health and perspectives. The concerned acronyms are presented in Table 1. In addition, the list of notations used is presented in Table 2.

Table 1 List of acronyms

S/N	Acronym	Meaning	S/N	Acronym	Meaning
1	AI	Artificial intelligence	9	EEG	Electroencephalography
2	CVI	Consciousness validity index	10	EIS	Environmental inference stage
3	DDSE	Data storage sub-entity	11	FDSSE	Field data storage sub-entity
4	DME	Decision making entity	12	IA	Intelligence augmentation
5	DML 1	Distributed mind level 1	13	PMSE	Power management sub-entity
6	DML 2	Distributed mind level 2	14	PTSD	Post-traumatic stress disorder
7	DML 3	Distributed mind level 3	15	QoS	Quality of service
8	ECAE	Environmental contextual acquisition entity	16	SEAS	Subscriber entity alert stage

2.1 Memory modification neural technology for addressing trauma arising from painful memories

The discussion in this subsection examines related work in the aspect of using neural technology to address conditions such as post-traumatic stress disorder. It identifies advances in technologies and paradigms underlying the development of approaches used to address memory related disorders. In the context of the presented research, the discussion here is relevant because it examines the perspectives on the development of technology for addressing neural disorders and how they benefit from advances in computing technology.

Liivoja and Kroes (2020) recognizes that post-traumatic stress disorder (PTSD) is a memory disorder of the mammalian nervous system. The discussion in Liivoja and Kroes (2020) also mentions that different theories have been presented to improve the understanding of PTSD. It is recognized that advances in the perspective of neurosciences play a key role in designing PTSD therapies. The discussion recognizes that memory modification techniques are most suitable for addressing PTSD. However, memory modification technologies are deemed to have significant ethical concerns (Tan and Lim 2020, Erier 2011; Gilbert et al. 2021). Opto-genetic technology is used in Adamczyk and Zawadzki (2020) to achieve memory modification. The discussion in Adamczyk and Zawadzki (2020) demonstrates the memory modification utility of an invasive neuro-modulation technology. The concept of opto-genetics enables the realization of neuron behaviour manipulation using light. This requires making target neurons responsive to light and enables the realization of memory modification as envisioned in Liivoja and Kroes (2020). The discussion by Adamczyk and Zawadzki (2020) advances Liivoja and Kroes (2020) by recognizing that opto-genetics is a memory modification technology.

The focus of Liivoja and Kroes (2020) is on a conceptual role and perspective of memory modification for PTSD. However, Adamczyk and Zawadzki (2020) does not localize opto-genetics technology to address a given neuronal disorder requiring treating a memory disorder. The use of opto-genetics enables an level of selectivity and precision in neural control than existing techniques such as deep brain stimulation.

Nevertheless, the discussion in Adamczyk and Zawadzki (2020), Liivoja and Kroes (2020) recognize that memory modification raises significant ethical concerns. These neuro-ethical concerns arise from the change in the identity of the individual undergoing memory modification. An approach that is different to memory modification is presented and discussed in (Hu et al. 2017). Hu et al. (2017) propose painful memory retrieval suppression. The retrieval suppression technique prevents the triggering of painful memories. The activation of painful memories arises from intentional and unintentional retrieval events. It degrades intentional painful memory recall and unwanted memory expression. This is different from memory modification because it leaves the memory and synapse formation potential intact.

Han et al. (2020) present and discuss the optoelectronic synapse technology. The optoelectronic synapse is used for the realization of an artificial visual Perceptron system. The presented research is set in the context of artificial intelligence (AI) based system. These AI systems use bio-inspired techniques to design advanced robotic systems. The use of opto-genetic technology as proposed in Adamczyk and Zawadzki (2020), Han et al. (2020) is a form of intelligence augmentation (IA) (Hassani et al. 2020) that integrates human and automated capabilities.

The use of opto-genetics in Adamczyk and Zawadzki (2020) to aid memory modification is recognized to facilitate painful memory deletion. This process aids the process of developing and administering a potentially effective therapy. Given that the brain already demonstrates

Table 2 List of parameters and notations used in this paper

S/ N	Parameter	Meaning
1	α	The set of neurons in the mammalian nervous system
2	$\alpha_a, \alpha_d \in \alpha$	The d^{th} neuron in the mammalian nervous system
3	$\beta(a, a + 1, a + 2)$	The synapse between the $a^{\text{th}}, (a + 1)^{\text{th}}$ and $(a + 2)^{\text{th}}$ neurons
4	γ	Given as: $\gamma \in \{\beta(a, a + 1, a + 2), \beta(a + 1, a + 2, a + 3), \dots, \beta(a + m, a + n, a + p)\}$, $\alpha_{a+3} \in \alpha$, $\alpha_{a+m} \in \alpha$, $\alpha_{a+p} \in \alpha$, $m < n$, $p < n$, $n < p$, $p < n$ and denotes the set of synapses describing the considered memories
5	t_y	y^{th} epoch t_y
6	$I(\gamma, t_y)$	The trauma indicator of memory γ at the y^{th} epoch t_y
7	$I(\gamma, t_y) = 1$	The traumatic memory γ at the y^{th} epoch t_y
8	$I(\gamma, t_y) = 0$	The non- traumatic memory γ at the y^{th} epoch t_y
9	$\mathcal{L}$	The set of patches having sub-hairs
10	$\mathcal{L}_j, \mathcal{L}_j \in \mathcal{L}$	The j^{th} sub-hair
11	$\theta_1(\mathcal{L}_j, t_y)$	The detected electric field at the y^{th} epoch, t_y for the j^{th} sub-hair
12	$\theta_1(\mathcal{L}_j, t_y)$	The detected mechanical deflection at the y^{th} epoch, t_y for the j^{th} sub-hair
13	ϕ_L	Intensity of the opto-genetic brain invasive memory modification procedure
14	ζ	The set of light sources utilized in the opto-genetic memory modification procedure
15	ζ_j	The j^{th} opto-genetic invasive memory modification procedure's light source
16	$P_1(\zeta_j, t_y)$	The operational power of the j^{th} opto-genetic invasive memory modification procedure's light source
17	$I(\zeta_j, t_y) \in \{0, 1\}$	The indicator of the j^{th} opto-genetic invasive memory modification procedure's light source at the epoch t_y
18	$I(\zeta_j, t_y) = 0$	Inactive light source of the j^{th} opto-genetic invasive memory modification procedure's light source at the epoch t_y
19	$I(\zeta_j, t_y) = 1$	Active light source of the j^{th} opto-genetic invasive memory modification procedure's light source at the epoch t_y
20	$P_1(\mathcal{L}_j, t_y)$	The operational power of the j^{th} sub-hair $\mathcal{L}_j$ at the epoch t_y
21	$I(\mathcal{L}_j, t_y) \in \{0, 1\}$	Instantaneous indicator of the j^{th} sub-hair $\mathcal{L}_j$
22	S	Set of headbands
23	s_u	u^{th} headband
24	$P_1(s_u, t_y)$	The operational power of the u^{th} headband
25	$I(s_u, t_y) = 0$	Inactive u^{th} headband
26	$I(s_u, t_y) = 1$	Active u^{th} headband
27	C_1	Consciousness Variation Index as formulated for the existing approach
28	C_2	Consciousness Variation Index as formulated for the proposed approach

significant intelligence and plasticity, the use of opto-genetics technology is an IA technique. From an evolutionary perspective, it delivers the functionality and capability of assisted evolution. This is an important goal within the larger domain of bio-hacking as explained in (Orive et al. 2020). However, the relation between opto-genetics and the larger goal of biohacking does not receive consideration in our discussion.

Orive et al. (2020) recognizes that machine biology is a nascent area. In implementing different technologies and realizing the goal of positive biohacking, the mind–brain question arises. The perception in the mind–brain influences progress in neuro-assistive technologies that meet the goal of a positive use of machine biology and biohacking. Transcultural psychiatry provides a window into the multi-perspective thought on the mind–brain connection and evolution. This is because trans-cultural psychiatry incorporates cross-cultural and non-western psychiatry perspectives as seen in (Antic 2021a, b; Antic 2021a, b).

This consideration of multiple perspectives enables advances to be made in AI and IA. Transcultural psychiatry pioneered by Raymond Prince aims to develop a scientific correlate to non-western mental therapies. The research literature in (Prince 1975, Prince 1960a, b, Wintrob 2006) describes the efforts in this direction. In (Prince 1960a), a distributed simultaneous therapy for psychosis is described. This approach applies different therapies to aspects of the patient's body. This is done concurrently with varying time epochs having slight differences). It is also noted in (Prince 1960a) that this therapy implemented a form of shock therapy. This shows that the underlying thought is that the mind is distributed and also experiences distributed disorders. However, the perspective of a distributed mind and its applications to designing data driven solutions and technologies has not been considered in research.

The discussion in this subsection shows that there are significant advances in developing memory modification technologies for addressing neural and mental related disorders. It is also recognized that the perspectives from psychiatry play a significant role in developing solutions (therapies) in the considered context.

2.2 Mobile devices, technologies, and neural applications

This subsection discusses existing research in the aspect of using mobile devices to host and execute neural technologies and applications. It presents a discussion and review on the existing research in the area of using computing and networking devices (inclusive of wearables) to host neural related therapies and solutions. The discussion is relevant as it presents existing research on how computing and networking devices have played a role in

enabling the development and use of neural related therapies.

The discussion here presents a future model for enabling the realization of a mobile device assisted grief therapy model. The proposed solution is intended for use by subscribers with impaired or non-existent hand–motor skills. Hence, the subscriber being considered is not able to hold a mobile device but capable of unaided mobility. The proposed solution presents a novel non handheld and head borne mobile communications device. It extends existing research that focus on the design and use of smartphone-based brain scanner. The smartphone-based brain scanner is described in (Huckins et al. 2019; Stopczynski et al 2014). The discussion in (Stopczynski et al 2014) presents a smartphone-based portability real time neuro-imaging system. It is recognized that technology advances has enabled the realization of neuro headsets that can monitor brain activity (Al-Kaf et al. 2020, Benitez et al. 2016, Wojck et al 2015). The focus on the development and use of neuroheadsets in existing research is the use of electroencephalography (EEG) technology for data acquisition and processing (Al-Kaf et al. 2020, Benitez et al. 2016, Wojck et al 2015). However, these neuro headsets are not integrated with smart phones. Ladouce et al. (2019) and Zhu et al. (2019) present a mobile phone integrated EEG headset. The use of mobile EEG is applied for mobile observation of brain-activity i.e., developing a mobile brain sensing technology. This is used for extracting data to detect neuro-development disorder via biomarkers. The discussion in Ladouce et al. (2019) demonstrates the use of mobile EEG in analysing the use of the brain's attention resources. The focus in Ladouce et al. (2019) is on understanding the factors underlying the use of attention in the brain.

The studies in (Al-Kaf et al. 2020, Benitez et al. 2016, Huckins et al. 2019, Ladouce et al. 2019 Stopczynski et al. 2014, Wojck et al. 2015, Zhu et al. 2019) demonstrate how advances in mobile phone i.e., smartphone technology can be used for EEG related computation. The discussion in (Coldeway 2021; Jamil et al. 2021) presents a solution from Cognixion, a neural technology startup. The technology solution in (Coldeway 2021) presents a mechanism enabling the realization of communications for neuro-challenged individuals. However, a solution intended to address grief has not been proposed or integrated.

2.3 Emerging paradigm—internet of the senses

The discussion in this section examines existing research in the aspect of relations between internet access technology, and the occurrence of sensory over-stimulation. In addition, the review also aims to discuss existing research on

the relations between human–computer interaction and sensory over-stimulation.

Boddington (2021) identify and discuss the applications that can be developed by leveraging on human hyper-sensory concept of self. The hyper-sensory concept of self has emerged from the need to reduce human interaction due to the occurrence of the coronavirus pandemic. In addition, the discussion in (Boddington 2021) recognizes different applications and use of technology that can be developed by leveraging on the emergence of the hyper-sensory self.

Murray-Browne and Tigas (2021) present the emergent interface paradigm as a mechanism enabling the realization of individual specific features in human–computer interaction applications. The implied realization is executed using the technique of unsupervised machine learning. In the presented application, the abstractions of the body i.e., movement of the body is used to generate a sonified body version that generates sound.

Cesari et al. (2021) identifies that the occurrence of the Coronavirus global pandemic has led to an increase in the use of online learning tools. The use of online learning tools has led to the emergence of online learning environment and resulting psychological stress for students in the online learning environment. The fragmented perception of online learning is also recognized to significantly aggravate the psychological stress associated with learning in online environment. The identified psychological stress can be addressed by the proposed solution of learning in a multi-sensory environment. In the absence of the proposed multi-sensorial strategy, it is recognized that the extensive use of online learning i.e., immersion in online learning environment is observed to result in anxiety. The observed anxiety arises from the occurrence of cognitive and sensorial overstimulation. However, the use implementation of the multi-sensory based solution has not been considered from the perspective of alleviating the observed anxiety (arising from cognitive overstimulation). This is because the occurrence of cognitive overstimulation has not been considered as a precursor to the emergence of the observed anxiety in the online environment.

In addition, the solution being proposed in (Cesari et al. 2021) focuses on the application of online learning. This is done without focus on the relations between the occurrence of anxiety and the proposed solution of multi-sensorial stimulation. Furthermore, the discussion in (Cesari et al. 2021) has identified augmented reality and virtual reality as technology solutions to the observed challenge of the occurrence of anxiety associated with the use of online learning tools and engagement with online learning environments. The research presented in (Cesari et al. 2021) can be further enhanced and extended by considering other

computing contexts and environments besides that of the online learning application.

Skulmowski and Xu (2021) address the challenge of designing digital learning tools and experience with reduced cognitive load. This is done with the goal of limiting extraneous load associated with learning task presentation. The discussion in this case has focused on identifying different learning mechanisms and their ability to realize a reduced cognitive load. In addition, the use of cognitive load alignment is proposed to realize a reduced cognitive load with the focus of designing digital learning tools. In a manner similar to (Cesari et al. 2021), the discussion in (Skulmowski and Xu 2021) also focuses on the realization of cognitive friendly digital learning solutions and environments. This is done without consideration of other use cases related to digital technology (end-user devices) and applications.

A unique perspective on the role and use of multi-sensory experience is considered in relation to human food interaction in an online environment (Velasco and Obrist 2021). The presented research explores the various aspects in which humans relate with food. These are recognized as being physical, and emotional. In this case, the design of a multi-sensory solution for improving human food interaction has been recognized to be beneficial. The focus of (Velasco and Obrist 2021) is in designing and presenting the design principles required for the realization of multi-sensory human food interaction. In this case, the consideration of multi-sensory human food interaction has not been proposed in line with reducing observed anxiety associated with dealing in food. Instead, a multi-sensorial experience has been considered from the perspective of enriching the process of capturing the details in experiencing food in the physical and virtual (online) environment.

Soroya et al. (2021) propose a model that utilizes the stimulus–organism–response model to understand the effect of information seeking, information sources and information overload. The presented research recognizes that the occurrence of COVID-19 has led to the use of information sources to inform communities about safety measures. The availability of this significant information sources is recognized to lead to the occurrence of information overload. In addition, information overload is recognized to be capable of leading to information avoidance. The proposed solution advocates the use of techniques and strategies to realize effective information management. In this case, it is recognized that information seekers accessed COVID-19 related data from sources that are not causing information overload and anxiety. Research finding in (Soroya et al. 2021) validates the stimulus–organism–response framework and identifies individuals with high

exposure to internet information sources. This is done with the goal of executing information anxiety management.

Peng et al. (2021) examine effect of information overload in decision making in the context of online retailer customer. In addition, the neural mechanism underlying information decision making after the occurrence of information overload in the considered context also receives research attention. This is realized by mining the brain's time-varying networks after the occurrence and experience of information overload by consumers. The presented study recognizes that substantial amounts of information increases decision difficulty with consequences in decision delay and occurrence of more inefficiency. The focus of the work is on examining the impact of information overload on the brain (while examining the neural basis). However, additional research is required to design a solution to address the challenge of information overload from a neural perspective. In this case, the design of information pathways to limit the occurrence of cognitive overload is recognized to be beneficial. However, this has not received attention in (Peng et al. 2021).

The discussion in this section has focused on examining the existing literature in the area of sensory overstimulation and its relationship with the use of internet and associated technologies. The discussion shows that there are significant advances in existing research focusing on studying how interacting with the internet causes sensory overstimulation. However, there is a limited research on the design of neural friendly solutions enabling subscribers (and users of computing and networking devices) to avoid scenarios and contexts that can cause trauma. The perspective found in existing research and literature, and potential opportunities (drawbacks) are presented in Table 3.

2.4 Artificial intelligence—future role in mental health and perspectives

Minerva and Giubilini (2023) examine the suitability of using artificial intelligence to enhance the delivery of solutions in mental healthcare. The discussion in the paper presents a balanced view and perspective for the responsible use of artificial intelligence in enhancing mental health outcomes. It is recognized that the use of artificial intelligence is beneficial for delivering enhanced outcomes for individuals who find human interaction challenging. Examples of such individuals are those with autism, and soldiers (with post-traumatic stress disorder). The benefits arising from these cases is because the use of artificial intelligence enables the realization of a virtual treatment assistant. In addition, the use of artificial intelligence provides for a short gap in the number of required mental health professionals. An increased number of mental health

professionals become necessary due to the increased number of mental health patients. The outlook of the presented discussion focuses on how the incorporation of artificial intelligence can enhance the management of mental health treatment delivery. The discussion also considers the use of artificial intelligence in understanding the underlying mechanisms associated with health care solution effectiveness. However, the use of artificial intelligence in developing paradigms for invasive mental health solutions has not been considered.

The discussion in (Zhang et al. 2023) proposes the use of medical imaging technology to identify individuals who are significantly prone to experiencing mental health challenges. The crux of the presented discussion is that magnetic resonance imaging present brain alterations in individuals with increased proximity to experiencing mental health illnesses and conditions. The use of magnetic resonance imaging is complemented with artificial neural network for image-based inference, analysis, and decision-making. The magnetic resonance imaging technique is used to analyse images obtained from medical students. The rationale for the choice of medical students is that these group of students and individuals are recognized to be subject to significant stress levels. The discussion in the paper proceeds in the direction of describing the procedure for training the artificial neural networks using the image datasets. The image datasets serve as inputs to the trained artificial neural network. The outcome of the prediction process is the determination of the occurrence of negative mental conditions in the concerned individual. The use of the artificial intelligence-based solutions coupled with medical data obtained via magnetic resonance imaging has not been considered in the perspective of enhancing an understanding of the underlying mechanisms behind severe mental illness. Minerva and Giubilini (2023) considers such an application path where the potential use of artificial intelligence to enhance the underlying biological mechanisms is considered. The considered underlying biological mechanisms are those that influence the selective effectiveness of the mental health related therapy solutions.

Hitti et al. (2023) present a multi-disciplinary perspective to the treatment of psychiatric disorders such as treatment resistant depressions. Treatment resistant depression is deemed to have arisen when multiple treatment trials has failed to address major depressive disorder. The use of the method of deep brain stimulation has been recognized to be a suitable treatment method for a considerable number of neurological disorders. The deep brain stimulation approach has been recognized to be a neuro-modulator-based therapy that functions via the modulation of brain activity. Neurosurgery is recognized as a cardinal approach in the multi-disciplinary perspective that has been presented in the discussion by (Hitti et al. 2023). However,

Table 3 Perspective and drawback in existing research (and literature)

S/N	Existing research	Description	Drawback
1	Liiivoja et al. (2020)	Presents PTSD as a nervous system memory disorder. The presented research recognizes the suitability of the memory modification technique of opto-genetics in addressing PTSD via neuron behaviour manipulation	The presented research does not consider the ease of subscription by low income and middle-income individuals. This is because the presented procedure has prohibitive costs. In addition, the use of neuron behaviour manipulation has a high potential of altering the consciousness of the concerned individual
2	Adamczyte and Zawadzki (2020)	The discussion here focuses on the neuro-ethical concerns associated with memory modification and emergence of a new individual	The research has not considered the design principles or alternative approach to ensure a low variation in individual consciousness or identity in an effort to re-design the process of memory modification
3	Orive et al. (2020)	Presented research examines paradigms on mind–brain relations and the influence on neuro-assistive technology development. This is examined in the context of designing positive bio-hacking related technologies and applications	Additional research on extending the scope of opto-genetics and other neuron modification technologies in line with addressing neural and memory disorders is required
4	Al-Kaf et al. (2020)	Focus is on the description of a user localized device i.e., the neuroheadset and discusses its role in monitoring brain activity	Additional research is required to discuss how neuroheadsets can be integrated with mobile technologies in a larger context in realizing value added applications
5	Coldeway (2021) & Jamil et al. (2021)	The discussion here presents a neuro-assistive solution from a technology start-up. The solution is intended to enable communications for individuals with neural challenges	The discussion has not examined the potential of embedding value-added solutions in the presented neuro-assistive technology. This can be addressed by describing how the presented technology can find applications in other domains
6	Boddington (2021)	The discussion recognizes the emergence of the hyper-sensory self as an additional dimension. This dimension arises due to the increased use of technologies embodying human–computer interaction	Further research is required to design a data framework to provide a guideline in developing applications utilizing the hyper-sensory self
7	Murray-Browne and Tigas (2021)	The discussion presents the emergent interface paradigm for generating a sonified body version from human movements in the context of human–computer interaction. The implied generation is executed via unsupervised machine learning	Additional research is required to develop applications making use of the sonified body version in integrated mobile applications
8	Skulmowski and Xu (2021)	Presented research focuses on designing digital learning solutions with low cognitive load	Future research that focuses on cognitive load reduction in other applications is required

the focus of the multi—disciplinary perspective is limited. The limitation arises because of the inclusion of medical related personnel without significant mention and description of the use of artificial intelligence technology. However, additional research and consideration is required to examine the benefits associated with the inclusion of technology experts in the multi-disciplinary perspective and approach. Furthermore, it is important for future multi-disciplinary initiatives to consider the development of alternative approaches. In this case, the alternative approaches enable the identification of important biological mechanisms. The important underlying biological mechanisms are those associated with treatment resistant mental conditions.

The discussion by (López-Ojeda and Hurley 2023) presents the influence of modern technologies in the area of neuroscience with a focus on clinical value laden solutions.

The usefulness of the large language model as an emerging artificial intelligence tool and algorithm receives attention in the discussion by (López-Ojeda and Hurley 2023). The outlook in (López-Ojeda and Hurley 2023) is similar to that in (Zhang et al. 2023) because it recognizes that the use of artificial intelligence is beneficial to enhanced mental health outcomes in individuals. Artificial intelligence approaches such as the large language model is recognized to play a crucial role in early detection of neurodegenerative disorders. In this regard, the use of memory related quantitative measures is recognized to be beneficial for the treatment of Alzheimer's disease.

In addition, the use of artificial intelligence is recognized to be beneficial to designing, developing, and assessing drugs suitable for treating mental health conditions. In addition, the use of large language based artificial intelligence models in medical education with focus on

psychiatry and neurosciences and associated assessments is recognized. Furthermore, the use of artificial intelligence methods in neuroscience and its clinical aspects is recognized to have significant value. However, it is important to also describe the ethical implications of the use of artificial intelligence for the provisioning of education in clinical neurosciences in greater detail.

The advancements in the use of artificial intelligence technology with the emergence of tools based on large language models is recognized by Caliyurt (2023). Caliyurt (2023) recognize that advances in technologies has enabled the emergence of methods that have significantly enhanced the delivery of mental health treatment. An important direction that requires further consideration is the use of artificial intelligence approaches to significantly enhance our understanding of mechanisms in the biological systems. In addition, the use of artificial intelligence to develop solutions enabling an improved understanding of the unexpected side effects associated with different treatment methods is also desirable and required. The focus of the use of artificial intelligence has been in the aspects of information processing, analysis, and image processing as seen in (Yeung et al. 2023). An important application of artificial intelligence is one in which the understanding of the mechanisms underlying the biological system is described. Such an application perspective and direction is presented in (Jung et al. 2023). An additional discussion that proposes the use of artificial intelligence for improved understanding of the biological mechanisms via biomarker discovery and heart failure causes is proposed in (Raikar et al. 2023), and (Mohammad 2023), respectively.

An important perspective presented in (Stratton 2023) posits a unique perspective from the research literature that has been cited in this section. The previous consideration of existing research literature focuses on the differing ability of artificial intelligence mechanisms and approaches to address different neurological challenges. This is the perspective presented in (Minerva and Giubilini 2023, Zhang et al. 2023, Hitti et al. 2023, López-Ojeda and Hurley 2023, Caliyurt 2023, Yeung et al. 2023). The consideration in the presented research has not focused on information emergent paths in the brain and its influence on the treatment of neurological disorders. The discussion in (Stratton 2023) recognizes that the brain is not merely an information processor but a creator of information in its interaction with the environment. However, this perspective has not been considered in the research discussion in (Stratton 2023). Such a perspective of information creation due to environmental interaction is recognized to be important for future considerations of artificial intelligence and associated applications. However, the perception of the brain being a creator of information via environmental interactions requires further research consideration.

3 Problem description

The challenge being addressed in this paper is described in this section. It considers the brain as comprising multiple neurons. Let α be the set of neurons (communicating via synapses) in the nervous system such that:

$$\alpha = \{\alpha_1, \alpha_2, \dots, \alpha_N\} \quad (1)$$

The memory described by the neurons $\alpha_a, \alpha_{a+1}, \alpha_a \in \alpha, \alpha_{a+1} \in \alpha$ and $\alpha_{a+2}, \alpha_{a+2} \in \alpha, a+2 \leq A$ is denoted $\beta(\alpha_a, \alpha_{a+1}, \alpha_{a+2})$. The memory $\beta(\alpha_a, \alpha_{a+1}, \alpha_{a+2})$ is triggered when synapses link the neurons α_a, α_{a+1} and α_{a+2} . Though the memory being considered involves three neurons i.e., α_a, α_{a+1} and α_{a+2} , it is possible to have two or more neurons being co-fired and linked via a synapse to cause a memory event. In addition, let $I(\gamma, t_y) \in \{0, 1\}$. The memory γ is traumatic and non-traumatic at the epoch t_y when $(\gamma, t_y) = 1$ and $I(\gamma, t_y) = 0$, respectively. Traumatic memories occur in the manner:

$$\{I(\beta(a, a+1, a+2), t_y), I(\beta(a+1, a+2, a+3), t_y), \dots, I(\beta(a, a+1, \dots, m), t_y)\} = \{1, 1, \dots, 1\} \quad (2)$$

$$|\beta(a, a+1, \dots, m)| > |\beta(a+1, a+2, a+3)| \quad (3)$$

$$|\beta(a, a+1, \dots, m)| > |\beta(a, a+1, a+2)| \quad (4)$$

$$|\beta(a+1, a+2, a+3)| > |\beta(a, a+1, a+2)| \quad (5)$$

The relation in (2) shows that the memory associated with the co-firing of the concerned neurons and associated synapses are all traumatic since the value on the right-hand side is 1.

$I(\gamma, t_y) \in \{0, 1\}$ is the trauma indicator of memory γ at the y^{th} epoch t_y . In the trauma indicator variable, the memory γ is defined such that: $\gamma \in \{\beta(a, a+1, a+2), \beta(a+1, a+2, a+3), \dots, \beta(a+m, a+n, a+p)\}, \alpha_{a+3} \in \alpha, \alpha_{a+m} \in \alpha, \alpha_{a+n} \in \alpha, \alpha_{a+p} \in \alpha, m < n, n < p, p < n, t_y \in t, t = \{t_1, \dots, t_Y\}$.

The case in (2) is one in which traumatic memories evolves at the y^{th} epoch t_y . The relations in (3)–(5) show an increase in the number of neurons and size of synapse. The relations in (2)–(5) are triggered via individual exposure to negative external stimuli. A scenario where the trauma status changes across multiple epochs is also feasible. This is described by:

$$\{I(\gamma_m, t_y), I(\gamma_m, t_{y+1}), I(\gamma_m, t_{y+2}), I(\gamma_m, t_{y+3}), \dots, I(\gamma_m, t_{y+j})\} = \{1, 1, 0, 0, \dots, 1\} \quad (6)$$

$$t_{y+1} \in t, t_{y+2} \in t, t_{y+3} \in t, t_{y+j} \in t, y+j \geq Y \quad (7)$$

The scenario in (6) involves multiple memories with activity across multiple time epochs. In this case, the memory has a varying trauma status at different epochs in

the considered scenario. The challenge presented in the scenario described by (2)–(5) is for a case of mass episode of traumatic memories at all time epochs under consideration. The scenario for a case considering all memories as:

$$\{I(\gamma_z, t_y), I(\gamma_z, t_{y+1}), I(\gamma_z, t_{y+2}), I(\gamma_z, t_{y+3}), \dots, I(\gamma_z, t_{y+j})\} \\ = \{1, 1, 1, 1, \dots, 1\}, \gamma_z \in \gamma \quad (8)$$

The scenario in (8) describes the case of mass trauma memories in an individual for a duration spanning the y^{th} epoch and $(y + j)^{th}$ epoch. The case in (6) is for the case of a non-mass episode of traumatic memories. The challenges associated with (2)–(5) and (6) and (7) is ensuring the non-traumatic memory at the concerned epochs. A solution that addresses the identified challenges enables the realization of the scenario:

$$\{I(\gamma_z, t_p)\} = 0, p \in \{y, y + 1, y + 2, y + 3, \dots, y + j\} \quad (9)$$

The use of memory modification technique enables the realization of the transition from the scenarios in (2)–(5) to (9) and (6), (7) to (9). These transitions describe the role of the proposed solution. The relations in (2)–(5) and (6) and (7) describe the triggering of mass traumatic and non-traumatic episode of memories in an individual, respectively. The scenario in (9) arises after using proposed solution. This is one in which there are no traumatic memories or when the individual is aware of the occurrence of traumatic episodes.

4 Proposed mobile–neural friendly architecture and associated paradigms

This section presents the solution that addresses the identified challenges. It has three subsections. The first section presents the distributed mind and consciousness paradigm. The second section discusses the first sub-solution enabling the identification of episodes with potential traumatic and non-traumatic states. This is done with a goal to inform and elicit the concerned mobile subscriber. The third section presents the second sub-solution and focuses on the hair based and data driven traumatic and non-traumatic episode recognition approach.

The second section focuses on the mobile device non-memory erasure grief therapy. This addresses the neuro-diverse trauma approach challenge. The third section presents the future generation bio-inspired hair communication network and system. The induced neuronal evolution therapy is also presented in this aspect.

4.1 Novel distributed mind and consciousness paradigm

The proposed distributed mind and consciousness paradigm posits that the concept of the mind is coupled to the neuron. In this perspective, consciousness can be influenced from any part of the mammal where neurons or nerve endings can be found. The notions for this can be found in (Prince 1975, Prince 1960a, b, Wintrob 2006). This implies that nerve endings that are distant from the brain can influence other actions in the mammalian body and behavior. The observation fit into the perspective in the integrated information theory (Liu 2020; Cea 2020). The integrated information theory holds the view that the claustrum enables the emergence of consciousness via multi-sensory information aggregation.

The functionality of the claustrum in this case is to enable multi-sensory information fusion of neural processing and decision making. In the proposed distributed mind and consciousness paradigm, the function of multi-sensory information aggregation is executed by neuronal assemblies at various parts of the mammalian nervous system. These neuronal assemblies can be found in various aspects of the mammalian nervous system where neurons can be found. The neuronal assemblies execute functionalities similar to that of the claustrum. They execute multi-sensory information pre-aggregation and pre-processing. However, they are different from the claustrum as they do not have a direct interface to the brain.

The proposed distributed mind and consciousness paradigm comprises three tiers i.e., distributed mind level 1 (DML 1), distributed mind level 2 (DML 2) and distributed mind level 3 (DML 3). DML 2 comprises neuronal assemblies that connect the nerves and the claustrum. The main entity in DML 3 is the brain. DML 1 hosts neuronal assemblies. The neurons in DML 1 constitute neuronal assemblies that are connected to the neuronal assemblies (linking nerves and the claustrum) at the level of DML 2. The entities that constitute DML 2 are linked with the entity at DML 3 (main entity is the brain). The relation between DML 1, DML 2 and DML 3 is shown in Fig. 1. In Fig. 1, the brain at DML 3 is realized via a large—neuron model that are inter-connected at a macro-assembly level.

The presentation in Fig. 1 shows the relations between DML 1, DML 2, and DML 3. Each of the DML hierarchy and level comprises the combination of different neurons and incorporates neuronal heterogeneity. Different heterogenous neurons are grouped in varying neuronal assemblies. The number of neuronal assemblies is different in each DML hierarchy. In Fig. 1, DML 1, DML 2, and DML 3 has one, three and four grouped neuronal

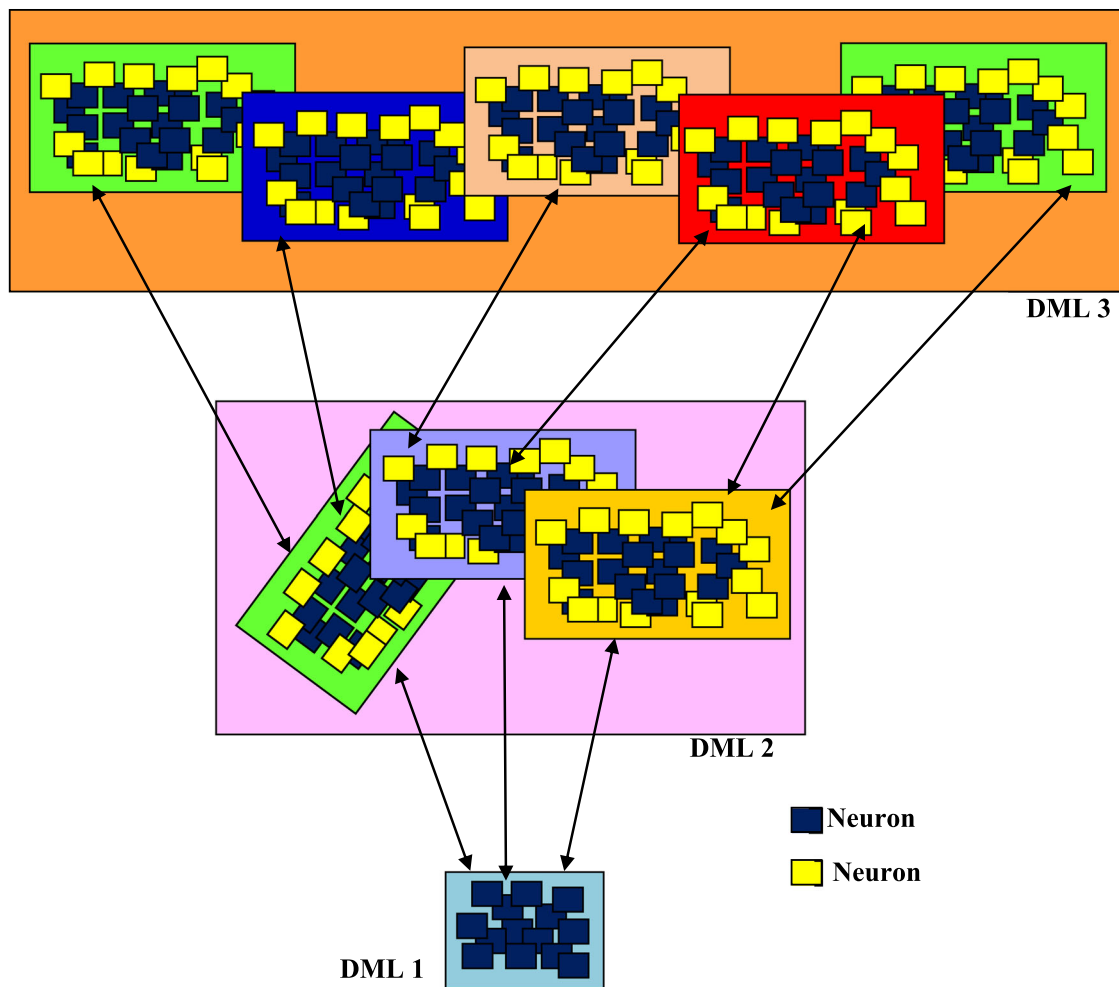


Fig. 1 Relation between DML 1, DML 2 and DML 3 in the distributed mind and consciousness paradigm

assemblies, respectively. The grouped neuronal assemblies overlap in DML 2 and DML 3.

From the perspective of transcultural psychiatry (Prince 1960a), the nervous system can be excited at any point of the three-tier distributed mind and conceptual model. The sense organs i.e., eyes (sight), ears (hearing), nose (smelling), tongue (tasting) and skin (feeling) are the main points of excitation. This also includes additional sources that have not been considered in the conventional domain. Given that the only sense organs for interacting with the external world are the conventional sense organs, it becomes challenging to interact with the external environment and develop any perception.

However, the discussion in (Prince 1960a) recognizes the presence of treatments with similarities to the shock therapy being mediated via chemical means. This raises the notions that the sense organ of the skin responsible for feeling can be deemed to comprise subtypes of sense organs capable of executing distinct functions. Hence, the process of nervous system excitation can be done without

necessarily considering if the point of excitation is a sense organ or not. The integration of multi-sensory information at any point along the three-tier distributed mind model is presented in the proposed solution. The integration is recognized in the integrated information theory of consciousness (Cea 2020).

4.2 First sub-solution for traumatic and non-traumatic state identification

The technology solution developed by Cognixion and presented in (Coldeway 2021) presents a mechanism enabling the realization of communication for neuro-challenged individuals i.e., subscribers. However, a solution intended to address mental health with a focus on depression and the associated grief has not been presented. However, this is deemed important when considering the neuro-developmental domain from the perspective of wireless communications. Such a notion is important due to the increasing development of high data rate technology

with capability to improve subscriber quality of service. Given that significant advances are being made in the direction of designing technologies capable of delivering high quality of service (QoS), it is important to extend wireless networks to new subscribers. The discussion here presents a two-stage solution. The first category and second category considers subscribers with and without good vision i.e., eyesight capability, respectively. A two-stage solution is described for these subscribers. This two-stage solution is intended to enable the accurate classification of a scenario as being either traumatic or non-traumatic. The first stage comprises a machine learning image-based scene classification sub-solution. The second stage comprises a scenario image classification sub-solution.

The first sub-solution being presented enables the identification of grief occurring epochs alongside the event triggers. In executing its function, the first sub-solution has access to different environmental scenarios and contexts. These scenarios and contexts are labelled as being traumatic or non-traumatic. The scenarios and environmental contexts are presented to the subscriber via prompts on the computing entity and end user device. The concerned device in this case could be a mobile phone (smart phone), tablet, laptop, or personal computer.

In the proposed first sub-solution, the trauma and non-trauma status of a given set of mass and non-mass episodes are visually communicated to the subscriber via messages displayed on a lens via differently displayed colors. Differently displayed colors are used to communicate and signify the notion that a given scenario and context within which the subscriber is located is either non-traumatic or traumatic. The proposed solution is an artificial intelligence solution that is developed in six stages. These stages are: (1) scenario and contextual image acquisition and classification, (2) scenario labelling, (3) learning model development, (4) intelligent solution deployment, and (5) field image acquisition and (6) subscriber notification.

In Stage 1, the process of contextual image and classification is executed by labelling scenarios as being traumatic or non-traumatic. The labelling can be done by an individual or multiple individuals. This requires that individuals identify images and scenarios that are deemed traumatic and non-traumatic. Images can be gotten by selectively activating the camera on mobile computing entities i.e., smartphones, and tablets when individuals (subscribers) change their location. In addition, computing entities that enable the initiation and completion of calls can also be utilized in this manner. For example, an individual can be asked to indicate the traumatic status of a call (voice, video, or data) after call termination. The contexts and images realized in this manner are classified as being either traumatic or non-traumatic. The execution of the classification in this manner enables the allocation of

traumatic status as expected in stage 1. In a given machine learning application, the potential inputs are the: (1) location, (2) image (acquired via camera selective activation), (3) change of location, (4) call type (voice, data, or video) and (5) mobile number. The inputs that have been given can be used in the following scenario. For example, an individual can label an environmental context (image describing a cemetery) as being traumatic. During the course of browsing the web to access content, an image of a cemetery is then flagged as being traumatic for the concerned individual. In an head worn device with an image acquisition entity (such as camera), approaching the cemetery or another nearby location leads to a light indicator signifying that the occurrence of a traumatic event is imminent.

The stage of scenario and contextual image acquisition and classification involves the process of acquiring images and videos of different scenarios. These image and video data can be acquired globally for different contexts considering individuals i.e., potential subscribers. Synthetic images can also be used to consider additional scenarios. This is due to the demonstrated use of synthetic images in computer vision applications (Hinterstoisser et al. 2018). The stage of scenario labelling involves the identification of acquired image and video data as being either traumatic or non-traumatic. The acquired image or video and the associated label are utilized to train a scenario classifier in the learning model development stage. The learning model is utilized in the intelligent solution deployment stage.

The stages of scenario and contextual image acquisition and classification, scenario labelling and learning model deployment are associated with the proposed solution. The solution use machine learning for image classification.

This deployment involves the installation of the developed learning model in the mobile device that is head worn by the subscriber. The mobile device hosts low powered diodes that display either red or green lights in a lens attached to the head worn subscriber mobile device. The field image acquisition is executed by the camera aboard the head worn subscriber mobile device. The camera acquires the image of the subscriber scenario and the acquired image serves as an input to the installed and deployed learning model that has been deployed. The installed and deployed learning model classifies the scenario as either traumatic or non-traumatic leading to the activation of either the red or green low powered light.

In implementation, the first sub-solution comprises five entities. These are the: (1) environmental contextual acquisition entity (ECAE), (2) environmental inference stage (EIS), (3) decision making entity (DME), and (4) subscriber entity alert stage (SEAS). The ECAE hosts the image acquisition or video acquisition camera and acquires the state of the environment. It is integrated into the

headband and acquires images that serve as inputs into the developed and deployed intelligent solution. The ECAE is intended to be functional in both indoor and outdoor environment.

The images acquired in the ECAE serve as inputs into the EIS. The EIS classifies the images as being non traumatic, or traumatic. It becomes active after the successful image capture by the camera in the ECAE. The DME hosts image classification outputs from the EIS and holds this data to see if there is a change in the environmental context i.e., scenario being considered. A non-traumatic event is adjudged true when a threshold number of EIS related outputs are non-traumatic. The SEAS hosts a power unit that drives the subcomponents of the green or red light based on DME output. The sequence of action between the ECAE, EIS, DME and the SEAS is shown in Fig. 2. In Fig. 2, the SEAS comprise the power management sub-entity (PMSE). The PMSE acquires information on the available onboard power and camera power consumption.

In the architecture shown in Fig. 2, the images of trigger events are captured, acquired, and used as data to prevent future encounter with grief occurring epochs. The solution being presented considers that the subscribers have impaired hand motor skills making them unable to hold the mobile device but have good eyesight capability. The images are used in artificial intelligence applications that aim to derive correlation between the scenario in the pre-acquired images used for training and those encountered by subscribers in a real-world context. The flowchart for the first sub-solution is shown in Fig. 3.

4.3 Proposed solution—second sub-solution for traumatic memory identification

The second sub-solution is presented in this section. This is realized as a data analytic solution that hinges on the capability of hair to become excited due to the presence of electric fields. The discussion in (Herbert and Duffau 2020, Pandarinath and Ali 2019, Zakon 2016) shows that hair

provide the basis of communication due to mechanical deflection caused by detected electric fields in bumble bees. In addition, it is observed that incident electric field on the hair of the bumble bee excites the nervous system (Clarke et al. 2017; Kaplan 2013; Zakon 2016).

Hence, the use of bumblebee's hair as a record of the external environment at a given point in time is proposed. From the perspective of the distributed mind and consciousness motivated by insights from transcultural psychiatry, it can be seen that the hair can be considered as a subcomponent of the sense organ of the skin responsible for feeling in mammals. In the second sub-solution, we propose that the bumble bee hair be integrated into the headband and the value of the detected electric field and mechanical deflection be used as primary data. The primary data is obtained and used alongside the image for executing the episode trauma classification process.

The detected electric field and mechanical deflection are determined for each subscriber scenario and are not known apriori. Hence, a test period is proposed to enable the sufficient merge of data on mechanical deflection and electric field alongside different scenarios as described by ECAE outputs in the development of a general solution. The general solution is realized by integrating the first and second sub-solutions.

Let $\mathcal{h}$ be the set of patches (having sub-hair) in the hair patch being used in the second sub-solution such that:

$$\mathcal{h} = \{\mathcal{h}_1, \mathcal{h}_2, \dots, \mathcal{h}_A\} \quad (10)$$

For the j^{th} sub-hair $\mathcal{h}_j, \mathcal{h}_j \in \mathcal{h}$, the detected electric field and mechanical deflection at the y^{th} epoch, t_y are denoted as $\theta_1(\mathcal{h}_j, t_y)$ and $\theta_2(\mathcal{h}_j, t_y)$, respectively. The data on $\theta_1(\mathcal{h}_j, t_y)$ and $\theta_2(\mathcal{h}_j, t_y)$ are integrated alongside the value obtained for $I(\gamma, t_y)$ in the second sub-solution at the epoch t_y . In this integration, the traumatic stress for which $I(\gamma, t_y) = 1$ is deemed to be traumatic given that the

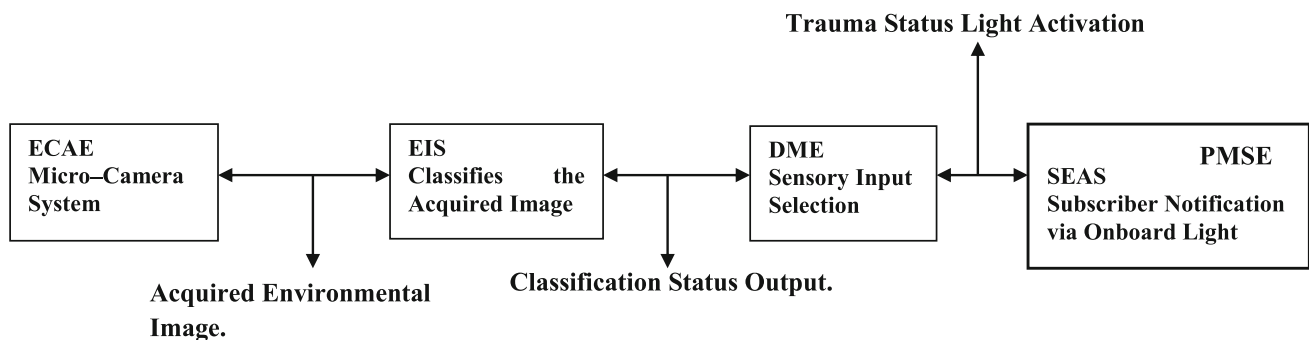


Fig. 2 Architecture of the first sub-solution showing the relation between the component blocks

Fig. 3 Flowchart for the first sub-solution being proposed

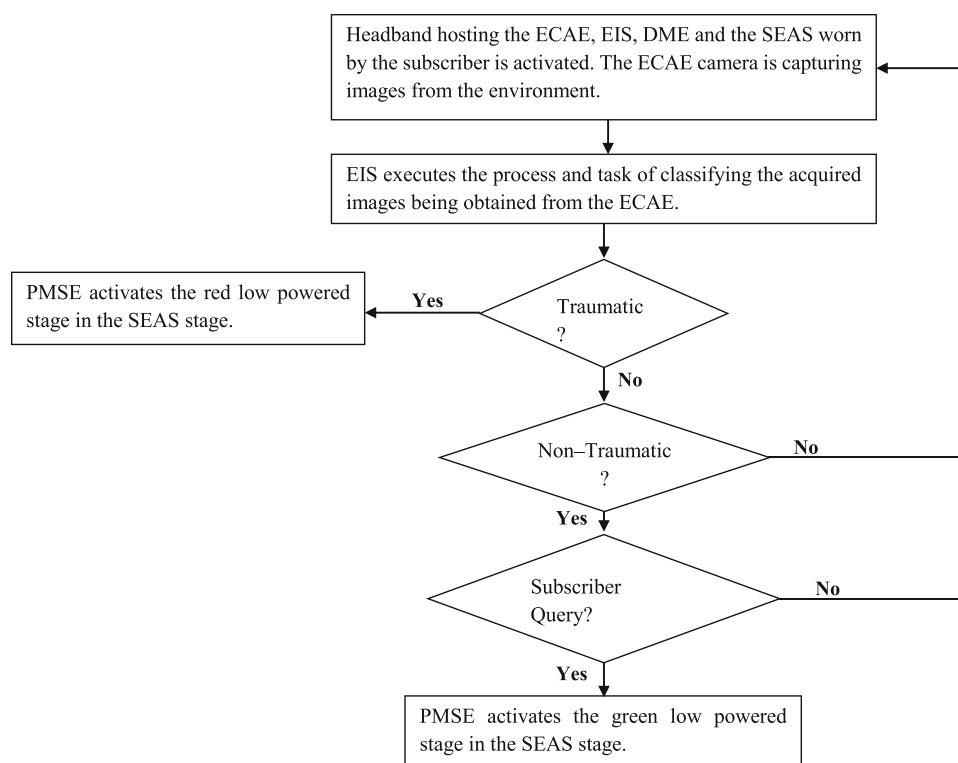


image classification signifies the presence of a mass or non-mass traumatic episodes alongside the conditions:

$$\begin{aligned}
 & \left(\left(\frac{1}{J-1} \right) \left(\sum_{j=1}^J \theta_q(\mathcal{L}_j, t_y) \right) \right) \\
 & \cong \left(\left(\frac{1}{F-J-2} \right) \left(\sum_{j=J+1}^F \theta_q(\mathcal{L}_j, t_y) \right) \right) \\
 & \cong \left(\left(\frac{1}{u-F-2} \right) \left(\sum_{j=F+1}^u \theta_q(\mathcal{L}_j, t_y) \right) \right) \quad (11)
 \end{aligned}$$

The consideration in (11) is for a hair patch with three separate groups of sub-hair patches. Each group comprises different number of sub-hairs. The first group, second group and third group have $(J-1)$, $(F-J-2)$ and $(u-F-2)$ hair patches, respectively.

In the formulation, the data on the mean electric field and mechanical deflection are integrated into the field and deflection data storage sub-entities. The Field Data Storage Sub-Entity (FDSSE) and deflection data storage sub-entity (DDSE) are hosted as sub-entities in the EIS (in the architecture of the first sub-solution). The EIS determines if the condition in (11) holds true using the values stored in FDSSE and DDSE. The values of 1 and 0 are the output of the EIS when (12) holds true and false, respectively. Therefore, the second sub-solution considers hair to be a record of data that can be used in neural computation and communications. An integration of the FDSSE and DDSE in architecture of the first sub-solution is shown in Fig. 4.

The architecture shown in Fig. 4 describes the solution proposed to enable the realization of the non-memory erasure approach for addressing grief in future network subscribers. In Fig. 4, the ECAE comprises the field sensing payload and the deflection sensing payload used to obtain the values of $\theta_{q=1}(\mathcal{L}_j, t_y)$ and $\theta_{q=2}(\mathcal{L}_j, t_y)$, respectively. These values are obtained for different sub-hair strands across multiple sub-epochs within a given epoch. An epoch is realized in a necessary context by considering that the computation described in (12) is executed for different sub-epochs.

In Fig. 4, the first stage i.e., the ECAE executes the task of acquiring the input. The inputs are parameters that can be used to infer a scene as being traumatic or non-traumatic. In this case, different payloads can be used. The payloads are of the types that sense the field, deflection, and image acquisition (via a camera). The output of this stage i.e., the ECAE is the acquired state of the environment. The acquired state of the environment serves as an input to the second stage i.e., the EIS. The EIS classifies acquired description of the environment and yields the classification status as the output. The classification status is either traumatic or non-traumatic. The third stage and fourth stage i.e., the DME, and SEAS are reconfiguration decision determination and reconfiguration decision execution stages, respectively. They enable the notification of the subscriber (or individual) about the traumatic or non-traumatic status of a given environment context.

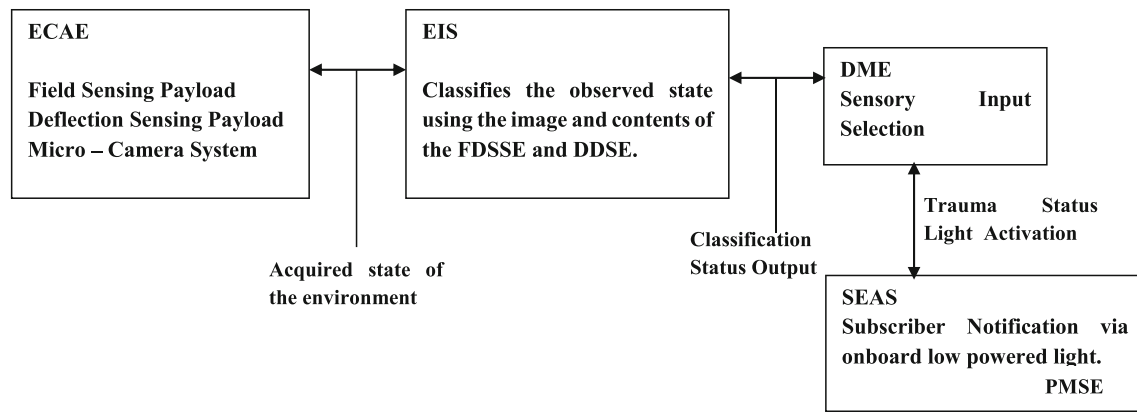


Fig. 4 Architecture of first and second sub-solutions with an integration of the new capabilities

The difference between the proposed architecture (first and second sub-solutions) and existing solutions (considered in Sect. 2 and highlighted in Table 2) are shown in Table 4.

A scenario that indicates the functioning of the proposed mechanism and solution is presented and illustrated in Fig. 5. The scenario in Fig. 5 concerns an individual utilizing a mobile user equipment and changing locations between three different contexts. These contexts are Scenario 1, Scenario 2, and Scenario 3. These scenarios are

classified as being traumatic or non-traumatic via the execution of the proposed solution as indicated in the flowchart shown in Fig. 3. The concerned individual is informed of the trauma status of these considered scenarios. The trauma status is determined using the proposed mechanism. In the case of a traumatic scenario, the concerned individual is informed of the risk of depression and therapeutic measures are executed. Therapeutic measures are specified by psychologist and their definitions (specification) are out of the scope of the presented research.

Table 4 A criteria–based comparison of existing solution and proposed solution

S/ N	Criterion	Existing solution	Proposed solution
1	Nervous system relations	Yes (memory modification, neuron behaviour modification via opto-genetic technology)—invasive	Yes: indirect relations with the nervous system—non-invasive
2	External scenario (or contextual) Classification	No	Yes (external scenes are classified either as traumatic or non-traumatic)
3	Mental health considered	No	Yes—the occurrence of depression is considered
4	Influence of electric field detection and mechanical deflection	None considered	Plays a significant role
5	Role of motor skills of individuals	Focus is on methods such as neuron behaviour modification, and other invasive approaches that do not consider motor skills	Receives significant consideration with focus on subscribers with limited or absent motor skills
6	Accessibility and cost	Existing invasive solutions require the execution of expensive surgical procedures with regard to memory modification	Proposed solution is intended to be accessible to subscribers that cannot access costly memory modification and neuron behaviour change procedures
7	Consideration of hair as basis of communication	No	Yes
8	Consideration of the motive of information overload avoidance	Yes	Yes
9	Mobile environment integration	Limited	Extensive

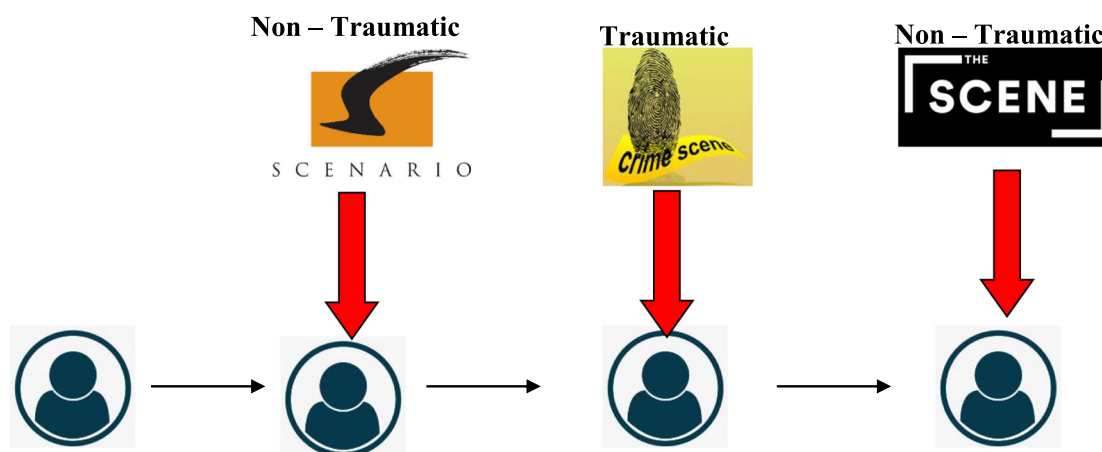


Fig. 5 Scenario showing the use case of the proposed mechanism

5 Performance formulation and modelling

The discussion in this section formulates the Consciousness Validity Index (CVI). The CVI is formulated as a mechanism to quantify how the use of invasive brain memory modification technology can influence the identity of the concerned individual. This concern is recognized in Adamczyk and Zawadzki (2020). The existing approach being considered is the invasive approach of opto-genetic based invasive brain neuromodulation with the end goal of memory modification.

In this section, a mathematical model is developed for the case of the existing approach and proposed mechanism. The existing mechanism utilizes opto-genetic based invasive brain neuro-modulation technology. The mathematical model is formulated by considering the parameters influencing the use of opto-genetic based invasive brain neuromodulation. The parameters being considered to describe the opto-genetic memory modifying neuro-modulation technique are: (1) size (i.e., number) of affected neurons, (2) size (i.e., number) of synapses concerned, (3) size (i.e., number) of laser light sources being utilized and (4) operational power of laser light sources. The number of neurons and synapses are $|\alpha|$ and $|\partial|$, respectively. The set of synapses ∂ is:

$$\partial = \{\beta(a, a+1, a+2), \beta(a+1, a+2, a+3), \dots, \beta(a+m, a+n, a+p)\} \quad (12)$$

In addition, the intensity of the opto-genetic brain invasive memory modification procedure is denoted ϕ_L . A low value and high value of ϕ_L implies low intensity and high intensity opto-genetic memory modification, respectively. Let ζ be the set of light sources used in the opto-genetic invasive memory modification procedure such that:

$$\zeta = \{\zeta_1, \zeta_2, \dots, \zeta_Z\} \quad (13)$$

The formulation of the CVI considers two components. The first component arises due to procedure-neuron interaction. The second component arises due to the operation of the concerned technology via electrically excited components. In the case of the existing scheme (opto-genetics (neuro-modulation technology)) for brain invasive memory modification (Adamczyk and Zawadzki 2020), the CVI, C_1 is given as:

$$C_1 = (\phi_L(|\alpha| + |\partial|)) + \left(\sum_{j=1}^Z \sum_{y=1}^Y P_1(\zeta_j, t_y) I(\zeta_j, t_y) \right) \quad (14)$$

$$0 \leq \phi_L \leq 1 \quad (15)$$

(ζ_j, t_y) is the operational power of the j^{th} opto-genetic invasive memory modification procedure's light source, $\zeta_j, \zeta_j \in \zeta$ at the epoch t_y .

$I(\zeta_j, t_y) \in \{0, 1\}$ is the indicator of the j^{th} opto-genetic invasive memory modification procedure's light source at the epoch t_y such that $I(\zeta_j, t_y) = 0$ and $I(\zeta_j, t_y) = 1$ indicates inactive and active light sources, respectively.

In (14), the first term and second term corresponds to the first and second components, respectively.

The CVI for the proposed case is formulated considering the following parameters: (1) operational power of sub-hair patches in the main hair patch, (2) performance of each sub-hair patch in electric field detection, (3) headband operational power and (4) headband operational status. In our formulation, the subscriber can use multiple headbands.

The operational power of the j^{th} sub-hair $\mathcal{H}_j$ at the epoch t_y is denoted as $P_1(\mathcal{H}_j, t_y)$. The activity status of the j^{th} sub-hair $\mathcal{H}_j$ at the epoch t_y is denoted as

$I(\mathcal{L}_{j,t_y}) \in \{0,1\}$. The j^{th} sub-hair $\mathcal{L}_j$ does detect and does not detect electric field in the environment context at the epoch t_y when $I(\mathcal{L}_{j,t_y}) = 1$ and $I(\mathcal{L}_{j,t_y}) = 0$, respectively. In addition, let S be the set of headbands such that:

$$S = \{s_1, s_2, \dots, s_W\} \quad (16)$$

The operational power of the u^{th} headband $s_u, s_u \in S$ at the epoch t_y is denoted as $P_1(s_u, t_y)$. In addition, let as $I(s_u, t_y) \in \{0,1\}$ denote the operational status of the u^{th} headband s_u . The u^{th} headband s_u is inactive and active at the epoch t_y when $I(s_u, t_y) = 0$ and $I(s_u, t_y) = 1$, respectively. The formulation for the CVI in the proposed mechanism comprises only the term reflecting the second component. This is because the proposed solution does not interact with neurons in its functionality as found in the existing brain invasive optogenetic memory modification via light. The CVI, C_2 for the proposed mechanism is:

$$C_2 = \sum_{y=1}^Y \left(\left(\sum_{j=1}^J P_1(\mathcal{L}_{j,t_y}) I(\mathcal{L}_{j,t_y}) \right) + \left(\sum_{u=1}^W P_1(s_u, t_y) I(s_u, t_y) \right) \right) \quad (17)$$

6 Performance evaluation and simulation

The discussion in this section investigates the instantaneous and cumulative CVI for the existing and proposed mechanisms using the parameters in Table 5. The instantaneous CVI is investigated to evaluate how the functional status of the opto-genetic light source influences the CVI. The cumulative CVI enables the evaluation of the total CVI at successive epochs.

The parameters used in the simulation and shown in Table 5 have been selected from existing work. This is with regard to the: (i) number of neurons (Bartheld et al. 2016), (ii) synapse to neuron ratio (Cullen et al 2010), (iii) number of light sources in opto-genetic invasive memory modification (Olofsson et al. 2021) and (iv) Light Source Power Consumption (Kampasi et al. 2018). In addition, the intensity of opto-genetic brain invasive memory modification is selected to have varying values of 0.3 (low intensity), 0.6 (moderate intensity) and 0.9 (high intensity). Furthermore, the memory modification procedure is executed 10 times i.e., ten epochs. The number of sub-hairs have been selected to have varying values from small (100) to significantly large values at 1–12 billion. This choice enables the evaluation of the performance benefit with increasing adoption of the proposed solution when more hairs are used. The power consumption of the headband has been considered to be 10W as this is sufficient to enable the execution of the proposed mechanism via the activated components.

The results for the instantaneous and cumulative CVI in existing mechanism i.e., Adamczyk and Zawadzki (2020) is shown in Figs. 6 and 7, respectively. The results for the instantaneous and cumulative CVI in the proposed scheme is presented in Figs. 8 and 9, respectively. The results in Fig. 8 shows a varying instantaneous CVI for different number of sub-hairs in the proposed solution. The cumulative results in Fig. 9 shows an expected non-oscillatory variation in the presented results. However, this is not case in Fig. 8 as the presented results considers the non-uniform variation in the headband operational power. The results in Fig. 8 have also been evaluated considering a varying headband operational status. However, the results presented in the case of cumulative CVI present a sum and cumulative values of the instantaneous CVI.

Table 5 Performance simulation parameters

S/N	Parameter	Value
Existing mechanism and approach		
1	Intensity of opto-genetic brain invasive memory modification	[0.3 0.6 0.9]
2	Number of neurons (Bartheld et al. 2016) and synapse to neuron ratio (Cullen et al 2010)	4,000,000; 15:1
4	Number of light sources in opto-genetic invasive memory modification (Olofsson et al. 2021)	4
5	Number of operational epochs in opto-genetic invasive memory modification technology	10
6	Mean, minimum and maximum light source power consumption (Kampasi et al. 2018)	[3.12, 0.488, 4.82] mW
Proposed mechanism and approach		
7	Number of sub-hairs	[100 1 × 10 ⁹ 1.2 × 10 ⁹]
8	Mean, minimum and maximum power sub-hairs	[0.66, 0.14, 0.97] mW
9	Number of headband and headband power consumption	[1, 10 W]

Fig. 6 Instantaneous CVI in the case of the existing mechanism

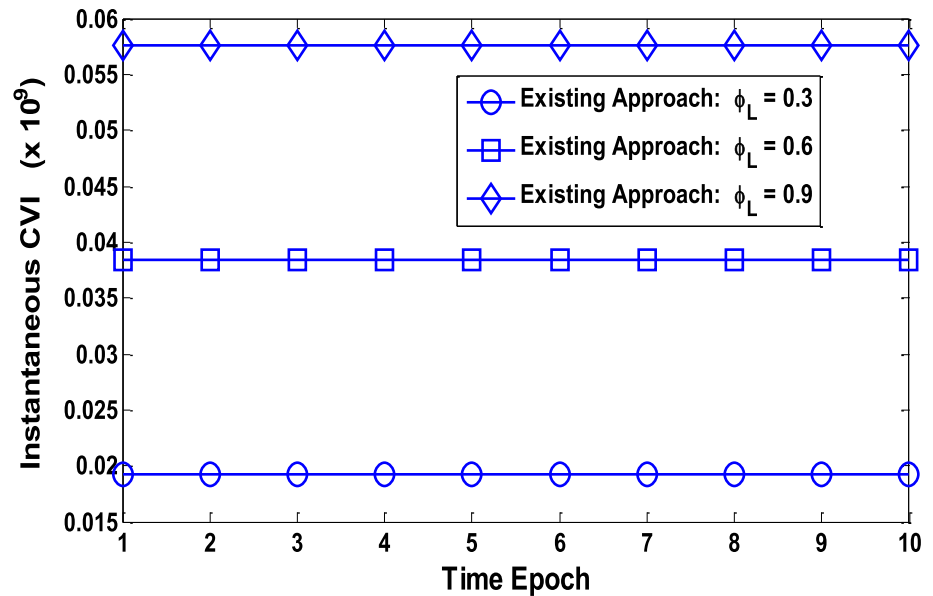
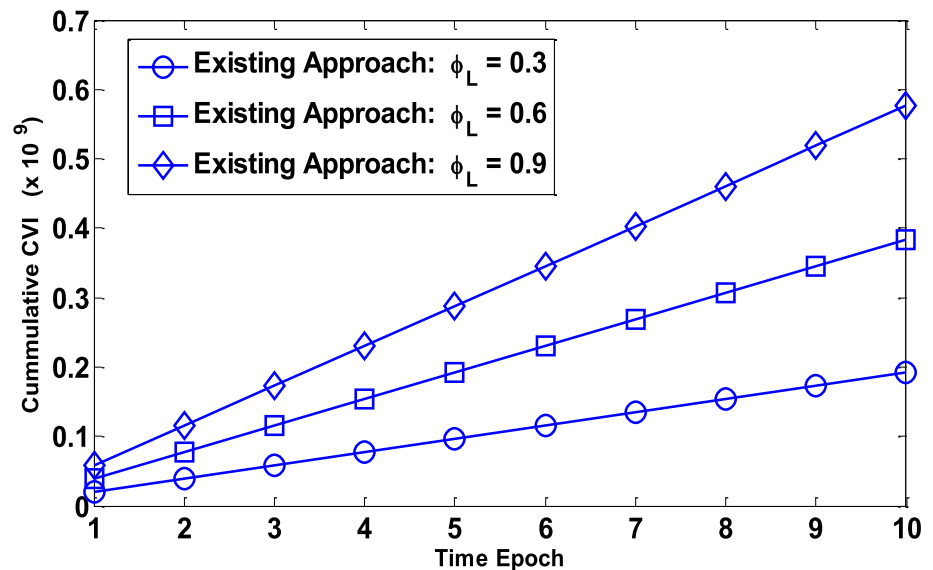


Fig. 7 Cummulative CVI for the case of existing mechanism

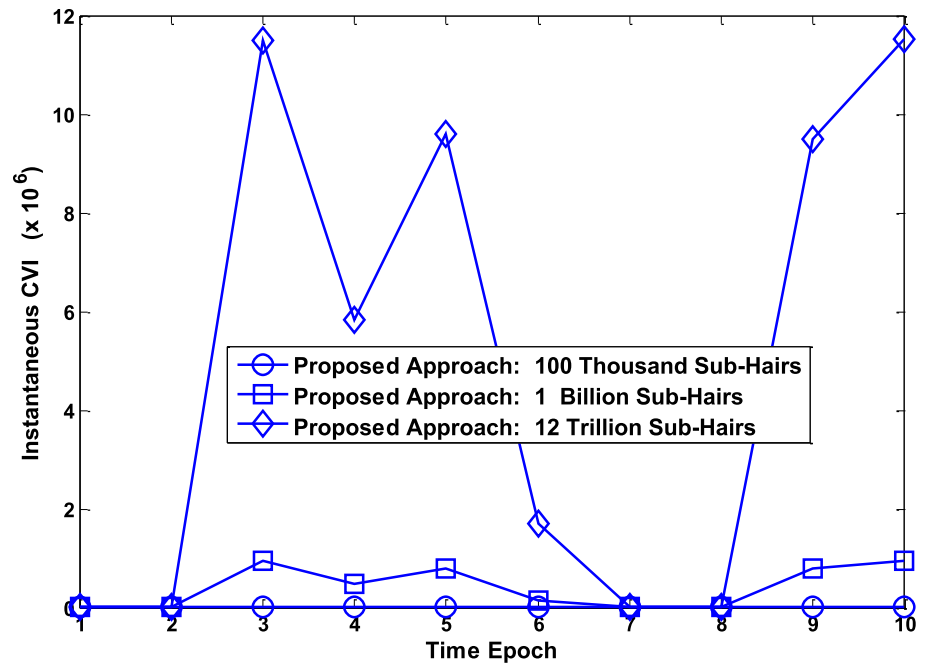
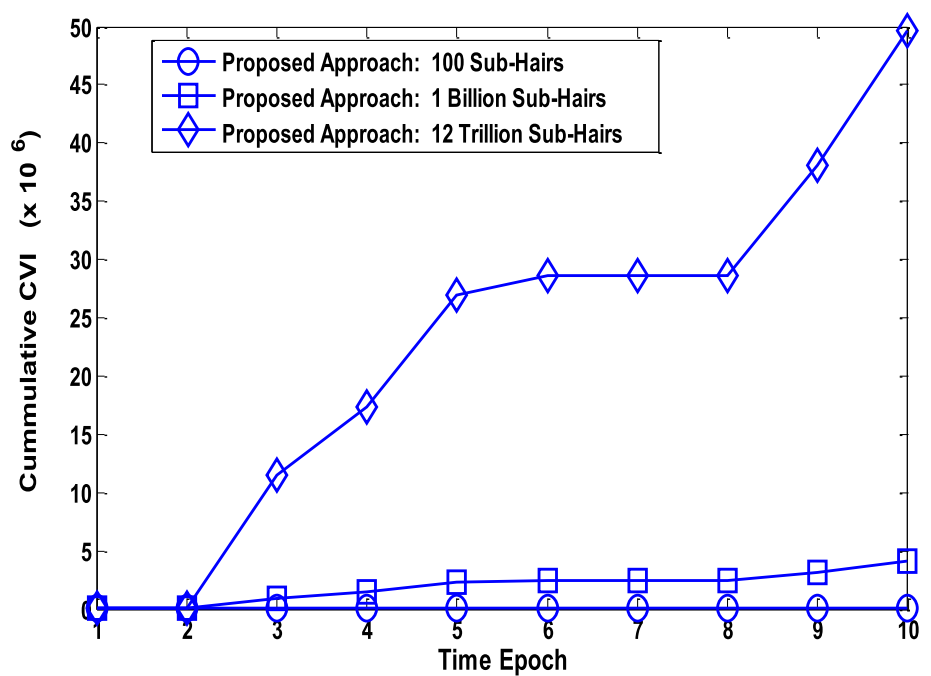


Analysis is done to investigate how changing the intensity ϕ_L influences the CVI C_1 for the existing mechanism. In the existing solution (Adamczyk and Zawadzki 2020), the increase in C_1 is observed to be equal to the percentage increment in the intensity ϕ_L . It is seen that the CVI increases by an average of 50%, 66.7% and 33.3% when the ϕ_L in the order of 0.3 to 0.6, 0.3 to 0.9 and 0.6 to 0.9, respectively. A similar increase in the CVI is observed for the cumulative CVI in the existing mechanism (Adamczyk and Zawadzki 2020).

The analysis also investigates similar CVI variation for the proposed mechanism. The influence of the number of sub-hairs is considered. In this case, the increase in the number of sub-hairs from 100 to 1×10^9 , 100 to 12×10^9 and 1×10^9 to 12×10^9 increases the CVI by 59%, 60%

and 55% on average, respectively. For the cumulative CVI, an increase in the number of sub-hairs from 100 to 1×10^9 , 100 to 12×10^9 and 1×10^9 to 12×10^9 increases the CVI by 79%, 80% and 73.3%, respectively.

The influence of the proposed mechanism in reducing the CVI is also investigated for a case of 100 sub-hairs. The use of the proposed mechanism instead of the existing mechanism (Adamczyk and Zawadzki 2020) reduces the CVI when compared to the case for which $\phi_L = 0.3$, $\phi_L = 0.6$, and $\phi_L = 0.9$. The use of the proposed mechanism when there are 1×10^9 sub-hairs reduces the CVI by 97.8%, 98.9% and 99.3% on average when compared to the case for which $\phi_L = 0.3$, $\phi_L = 0.6$, and $\phi_L = 0.9$, respectively. Furthermore, the reduction in the CVI when 1.2×10^{10} sub-hairs is compared to the case of the existing

Fig. 8 Instantaneous CVI in the proposed mechanism**Fig. 9** Cummulative CVI in the proposed mechanism

mechanism is also investigated. In this case, the use of the proposed mechanism when there are 1.2×10^{10} sub-hairs reduces the CVI by an average of 74.2%, 87.1% and 91.4% compared to the case $\phi_L = 0.3$, $\phi_L = 0.6$, and $\phi_L = 0.9$, respectively.

Performance analysis shows that proposed mechanism has a lower CVI than the existing mechanism (Adamczyk and Zawadzki 2020). It can be inferred that the mobile neuro-assistive technology in non-memory erasure grief is beneficial than invasive memory modification technology.

Hence, the CVI is reduced by (74.2%–99.3%) on average by using the proposed mobile-neuro assistive technology.

Further analysis is done to examine the mean performance benefit of the proposed solution over the existing solution. This is done considering varying values of ϕ_L alongside different number of hairs. The obtained results are presented in Tables 6, 7, and 8. The presented results show that the proposed mechanism outperforms the existing mechanism. In addition, it can be seen the performance benefit reduces with an increase in the number of sub-hairs

Table 6 Mean performance benefit of proposed mechanism for values of $\phi_L = 0.3, 0.6$ and 0.9

Epoch	Mean Performance Benefit			Mean Performance Benefit		
	$\phi_L = 0.3$ 100	$\phi_L = 0.6$ 1 Billion	$\phi_L = 0.9$ 12 Billion	$\phi_L = 0.9$ 100	$\phi_L = 0.6$ 1 Billion	$\phi_L = 0.3$ 12 Billion
1	100	98.9	91.4	100	99.3	82.1
2	100	99.4	95.4	100	99.3	82.8
3	100	99.4	95.3	100	99	75.4
4	100	99.1	92.8	100	99	76
5	100	99.3	94.3	100	99.2	81.6
6	100	93.3	94.5	100	98.9	74.6
7	100	99.6	97.0	100	99.6	91.0
8	100	99.1	93.1	100	99.2	81.7
9	100	99.4	95.5	100	99.4	86.4
10	100	99.3	94.6	100	99.2	81.3

Table 7 Mean performance benefit of proposed mechanism for values of $\phi_L = 0.4, 0.5$ and 0.7

Epoch	Mean Performance Benefit			Mean Performance Benefit		
	$\phi_L = 0.4$ 100	$\phi_L = 0.5$ 1 Billion	$\phi_L = 0.7$ 12 Billion	$\phi_L = 0.7$ 100	$\phi_L = 0.5$ 1 Billion	$\phi_L = 0.4$ 12 Billion
1	100	98.5	87.3	100	99.3	88.9
2	100	98.9	91	100	98.8	82.7
3	100	99.3	93.9	100	99.3	89.2
4	100	99.1	91.8	100	98.6	79.6
5	100	99.4	94.6	100	99.1	85.5
6	100	99.7	97.1	100	99.2	88.2
7	100	99.3	93.9	100	99.4	90.8
8	100	98.9	90.1	100	99.2	87.8
9	100	98.4	87	100	99.1	87.1
10	100	99.1	92.4	100	99.0	84.1

Table 8 Mean performance benefit of proposed mechanism for values of $\phi_L = 0.1, 0.2$ and 0.3

Epoch	Mean Performance Benefit			Mean Performance Benefit		
	$\phi_L = 0.1$ 100	$\phi_L = 0.2$ 1 Billion	$\phi_L = 0.3$ 12 Billion	$\phi_L = 0.3$ 100	$\phi_L = 0.2$ 1 Billion	$\phi_L = 0.1$ 12 Billion
1	100	96.9	75.6	100	96.9	75.6
2	100	97.9	83.2	100	97.9	83.2
3	100	97.8	82.1	100	97.8	82.1
4	100	96.9	75.1	100	96.9	75.1
5	100	96.9	75.1	100	96.9	75.1
6	100	97.3	78.1	100	97.3	78.1
7	100	97	75.8	100	97	75.8
8	100	97	76	100	97	76
9	100	98.4	87	100	98.4	87
10	100	98.2	85.4	100	98.2	85.4

being considered. This is because of the increase in the CVI associated with the proposed mechanism when the number of sub-hairs increases. It can also be seen that the

performance benefit reduces with a decreasing in ϕ_L for the same number of sub-hairs in a given consideration.

7 Conclusion

The research that has been presented discusses the role of computing networks in enhancing mental health of subscribers. The challenge that is been addressed is that of limiting and ideally preventing the occurrence of depression in individuals. In this case, the considered depression occurs when individuals experience scenes or environmental contexts that trigger traumatic episodes. The ideal solution in this case is to delete traumatic scenes and contexts that are stored as memories in the human brain. However, the realization of this solution is challenging. An alternative solution that can be considered in this case is memory modification. However, memory modification requires continuous execution especially when individuals repeatedly encounter traumatic scenes. The approach being considered in the presented research involves the use of computing networks and the associated access devices i.e., smartphones, tablets, laptops, and personal computers. The presented research proposes a solution to limit the encounter of individuals (subscribers) with traumatic laden scenarios, episodes, and contexts. It presents a novel multi-disciplinary solution involving relations between psychiatry, advances in machine learning and communication network capabilities. The proposed solution utilizes bumble bee hair for environment context classification to determine if a scenario or context is traumatic or non-traumatic. In addition, the proposed solution is non-invasive and does not alter individual notion of consciousness in comparison to existing invasive methods such as that of opto-genetics memory modification. The proposed solution aims to address the challenge of depression occurrence with limited variation of individual notion of consciousness. In addition, the research recognizes the individual's sense of being i.e., consciousness as a key performance metric. In this regard, the performance metric is the consciousness variation index. The choice of the performance metric is because the non-interruption of individual consciousness is integral to determining state of well-being. In addition, the research formulates and investigates how the proposed mechanism influences the consciousness variation index. Analysis shows that the use of the proposed non-invasive mechanism preserves the individual notion by (74.2–99.3) % on average. This implies that the use of the proposed approach is beneficial than the existing case of utilizing invasive surgery methods. The benefit arises because the proposed approach does not lead to a case where the individual's sense of being is significantly disrupted. A reduction in the interruption of the sense of being implies that the concerned individual is able to resume normal life routines and activities within a shorter time. The discussion in the presented research has been

conceptual and has a theoretical perspective. Additional work is required to implement the proposed solution in prototype and also evaluate the computational complexity of the proposed algorithm on selected prototype hardware.

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Data availability Data associated with the presented research is found within the body of the paper.

Code availability Not Applicable.

Declarations

Conflict of interest The authors declare that there are no conflicting interests.

Consent for publication All authors consent to publishing the paper.

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