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MULTISENSORY-LEARNING-ENVIRONMENTS: ARTIFICIAL INTELLIGENCE FOR THE DOMOTISATION AND REPLICATION OF LIGHTS AND SOUNDS THAT FOSTER THE STATE OF FLOW

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Abstract: This contribution aims to create a potential synergy among human, artificial intelligence, and the environment. The objective is to leverage the home automation of multisensory environments through the use of artificial intelligence software, in order to provide a multisensory learning context characterized by customization and calibration in delivering specific stimuli, particularly luminous and auditory stimuli. These stimuli aim to enable the individual to undergo a neurosensory experience that facilitates the achievement of the Flow state. The results related to the physiological activation state, attention levels, and brain activation of the individual, emerging from each experience, will be an integral part of the AI (Artificial Intelligence) software training. This is intended to obtain personalized and calibrated intervention protocols, tailored to the specificity of the users on each occasion.

Keywords: Digital Evolution; Empowerment; Cognition.

1. Introduction

In the current scientific landscape, the effectiveness of integrating technology and learning contexts is increasingly evident, aiming to determine the possibility of structuring environments that can benefit from the potential of the ongoing technological evolution (Chierichetti, Cittadini, et al. 2023). The literature highlights how the use of cutting-edge technologies such as AI can represent new opportunities to be incorporated into environments aimed at promoting benefits for individual learning processes (Okagbue et al., 2023). Specifically, the exploratory investigation focuses on the automation of multisensory environments by artificial intelligence software. Through this software, the goal is to provide a multisensory learning context that can be personalized and calibrated in delivering specific stimuli of a luminous and auditory nature, whose functional output is supported by a basic scientific literature

(Schmidt et al., 2011; Chen et al., 2022). So in the scientific landscape, it has been found that the use of specific visual and auditory wavelengths can favor a functional response for the implementation of cognitive processes, specifically in the attentional and mnemonic domain. Concerning luminous stimuli, it has emerged from various studies that exposure to blue light with wavelengths ranging between 460 and 480 nanometers is effective in increasing attention, vigilance, and reducing drowsiness, thus promoting improved cognitive performance, faster reaction times, and contributing to enhancing working memory performance, which plays a central role in learning processes (Alkotzei et al., 2017). As for auditory stimuli that acoustical stimuli calibrated at a frequency of 40 Hz increase the activity of brain gamma waves, which play a central role in the functioning of attention, perceptual, and memory processes in the brain (Negara et al., 2021). In this perspective, the objective is to provide the individual with controlled stimulation, proposing a home-automated multisensory environment that, by leveraging the potential of AI, becomes more advantageous, motivating, and favorable in the acquisition and enhancement of specific skills applicable and generalizable to different life contexts.

2. Multisensory Environment

The use of multisensory environments began in the early 1970s in the Netherlands as a non-pharmacological therapeutic technique for treating individuals with dementia. These environments are designed to provide engaging and immersive experiences by controlled activation of sensory channels through elements such as lights, colors, sounds, odors, and vibrations integrated into an artificial and controlled environment, aiming to enhance the overall experience of the individual.

The brain is a responsive system characterized by dynamism and plasticity, relying on stimulus-response mechanisms and intrinsically linked to experience (Siegel, 2001). The goal is to promote experiences involving various sensory stimulations. In this perspective, the close triangular relationship between the brain, body, and environment is exploited, where human action becomes fundamental in the learning aspect. Through multisensory stimulation, simultaneously activating multiple receptive organs and respective brain areas based on specific tasks, the aim is to contribute to fostering the learning and consolidation processes of the individual.

Scientific evidence has demonstrated its valuable support for individuals with disabilities through the creation of a holistic setting addressing mental, physical, and emotional-behavioral aspects (Rossetti & Tonetti,2023). It is possible to work on enhancing or recovering cognitive abilities through targeted stimuli that allow working on functions such as memory, attention, and concentration, positively influencing learning processes. Furthermore, it is possible to promote the enhancement of sensory channels by working on both bottom-up processes at the level of stimulus reception and top-down processes at the cortical processing level, fostering integration and contributing to the development of perceptions and the kinesthetic channel. Additionally, working on the social skills of the individual is achievable since these environments are protected and controlled, promoting exploratory autonomy and social interaction by understanding and respecting the emotional-relational modalities and timings of the individual to ensure the development of functional connections.

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2.1 Domotization and Multisensory Environment

The functional use of artificial intelligence in today's pedagogy can provide significant support for transformative changes in common educational practices, allowing for a more fluid and efficient experience. In the 21st century, it is essential to focus on the tools needed to assist in the transition of information acquisition methods, considering the shift from "old" to "new" contexts that reflect developments in various sectors, including the educational field. In this perspective, an analysis process linked to the use of innovative methodological tools that understand and structure responses to the educational needs arising in today's world becomes essential (Poquet et al., 2021). Supporting this new vision, tied to the use of educational practices that respond to the ever-changing demand for innovation, even in the pedagogical field, a systematic review in 2023 emphasizes the importance of promoting artificial intelligence devices that enhance the use of quality pedagogical services (Okagbue et al., 2023). Thus, the educational offer, taking place within an academic environment responsive to the most changing needs, suggests to school administrators to enact policies that support the acceptability and usability of artificial intelligence even in educational spaces. It follows that learning environments must evolve towards an applied-educational pedagogy that focuses on promoting acquisition and teaching methods characterized by fluidity in processes. AI plays a crucial and active role in creating educational settings that support engaging and stimulating tasks, directly influencing their categorization based on user needs. Multisensory environments, through the use of sounds, lights, odors, etc., integrate different sensory modalities, creating an immersive and personalized atmosphere that significantly enhances the individual's experience. The integration of AI within these environments adds value to the customization and calibration of stimuli defining such contexts. Specifically, the action of AI allows the support of interactive mechanisms linked to continuous issuance of personalized feedback that facilitates the development of a digital curriculum, as well as monitoring and saving learning progress (Srinivasan & Murthy, 2021). The ability to act directly and promptly in different stages of knowledge acquisition enhances the learning process, responding to the needs of the individual expressed in various ways and timeframes. In this perspective, it is possible to develop a protocol characterized by continuous acquisition of information on the level of competence reached by the student and on specific educational needs, to implement an educational intervention that influences and promotes learning performance (Lee & Lee, 2021). It becomes evident that AI allows simultaneous action on multiple fronts: enjoying feedback, acquiring and maintaining data, processing statistics, and creating intervention schemes that promote a more conscious learning of real and concrete educational needs within a controlled and regulated learning space. Training AI on a specific task allows the creation of new and responsive tools capable of increasing data from past models and providing increasingly dynamic support for specific needs.

3. Lights and Sounds for Attention

In light of the foregoing, the aim is to investigate the strategic use of light-sound integration in a learning context with the goal of enhancing students' attention processes. To achieve this, leveraging the potential of artificial intelligence in reaching the objective becomes almost obsolete not to do. In this direction, the research moves with the aim of defining innovative strategies to improve students' cognitive per-

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formance, specifically in attentional and mnemonic processes. This involves exploring solutions that act on a dual level: initially proposing intervention protocols within controlled multisensory environments, supported by AI, to deliver sessions of multisensory stimulation for attention enhancement. Following this initial phase, the goal is to subsequently replicate any beneficial effects in the classroom setting, benefiting frontal lessons, which are usually devoid of additional supports and where information is delivered from top to bottom. This conventional teaching methodology often renders the learner in a passive role, inevitably making them more susceptible to variations in attention levels (Lembo et al., 2023). In light of this, bringing the proposed setting from multisensory environments back into the classroom can be a functional response to the research objective. From this perspective emerges the interesting connection between the integrated use of blue light and sound frequencies at 40 Hz, aimed at optimizing attention and memory in multisensory learning environments.

3.1 Blue Light for Attention

Light plays a crucial role in regulating various circadian, neuroendocrine, and neurobehavioral functions, extending beyond image or visual-related responses, thanks to the action of intrinsically photosensitive retinal ganglion cells (ipRGC) (Schmidt et al., 2011). These cells, a recent discovery in the class of retinal photoreceptors, operate alongside rods and cones. They are maximally sensitive to short-wavelength blue light, approximately at 480 nm. Their activation is essential for multiple physiological and behavioral processes, demonstrating a fundamental role in modulating wakefulness and cognitive performance (Vandewalle et al., 2013). Exposure to light not only directly improves alertness and performance but also stimulates brain activity involved in higher cognitive processes, irrespective of the visual component. This complex interaction involves additional brain areas, contributing to a continuous flow of cognitive processes. This intervention is structured based on numerous studies reporting the positive effects of blue light, specifically at wavelengths of 460nm, on cognitive performance (Alkotzei et al., 2017; Imperiale, 2018; Beaven et al., 2013). Acute exposure to blue light, characterized by a wavelength of around 480 nm, not only impacts visual perception but extends to influencing circadian rhythms, sleep quality, and duration. This process is mediated by responses from intrinsically photosensitive retinal ganglion cells, transmitting signals to the suprachiasmatic nucleus (SCN). The SCN, as the body's main clock, regulates melatonin production and circadian rhythms of sleep and wakefulness, interacting with the locus coeruleus (LC) in the brainstem (Alkotzei et al., 2017). These preliminary indications suggest that targeted application of blue light could represent an innovative strategy to optimize mnemonic performance, offering extended possibilities for use in multisensory learning contexts (Alkotzei et al., 2017). The discovery that the alerting response to blue light is effective in reducing drowsiness and improving cognitive performance, especially in tasks related to concentration and cognition (Chellappa et al., 2011; Cajochen et al., 2011), has laid the foundation for an innovative approach to learning. Attention becomes the focus of this exploration since it is a crucial element in the knowledge and skills acquisition phase (Clark et al., 2023). The key to this connection between blue light and attention lies in the established ability of short-wavelength light to modulate alertness through melatonin suppression (Beaven et al., 2013). This physiological process offers the opportunity to shape the learning

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environment to maximize students' attention and, consequently, improve their academic performance, thus positively impacting the overall well-being of the individual within a context where the individual is evaluated from a bio-psycho-social perspective.

In conclusion, the strategic use of blue light in multisensory learning contexts appears as an effective perspective to enhance students' attention and cognitive performance. Based on the solid foundation of blue light's ability to modulate alertness through melatonin suppression, this in-depth exploration could open new horizons in the design of educational environments. Thus, the individual needs of students are considered by integrating light stimulation at specific wavelengths with other sensory stimulation. It is hypothesized that we are witnessing an evolution-revolution in the approach to the enhancement of learning processes. This result could redefine the concept of context by justifying its importance in the individual's developmental processes.

3.2 40 Hz Sound Frequencies for Attention

One of the fundamental considerations in the analysis of cognitive processes relates to the role played by sound and its oscillations in shaping brain activity. In particular, the aim is to delve into the positive influence of specific sound oscillations on the stimulation of attention processes. Attention is a complex cognitive process that involves selecting essential issues and disregarding less critical ones. Attention and concentration are equally important for the physiological and behavioral responses individuals exhibit in the contexts in which they operate. Recent significant research has explored the relationship between attention and sound, highlighting the potential impact of 40 Hz gamma oscillations, particularly encouraged by audiovisual stimuli, demonstrating a significant enhancement of brain functions (Chen et al., 2022). Gamma brainwaves, characterized by a predominant presence during states of full consciousness and high attention, prove to be susceptible to activation through exposure to carefully calibrated sound supports at a specific frequency. Scientific evidence shows that human gamma brainwave activity is significantly correlated with cognitive functions of attention and memory, both in sensory and non-sensory areas (Jensen et al., 2007). The resonance of these gamma frequencies becomes a key element in the context of neuronal communication and synaptic plasticity, playing a crucial role in neural processing. This defines the importance these waves have in cognitive functions. This activity not only concentrates at the local level but extends to distributed cortical networks involved in complex cognitive functions. Gamma brainwaves are fundamental in determining how central they are in the neural dynamics governing attention and memory. Given recent discoveries in neuroscience highlighting the crucial role of gamma oscillations in human cognitive function, this contribution aims to explore the relationship between the activation of these waves following sound stimulation calibrated to a specific frequency. Previous research has indeed highlighted that the application of audiovisual stimuli at a frequency of 40 Hz is associated with the induction of gamma oscillations, significantly enhancing the synchronization of these waves in the brain. This process has demonstrated to enhance cognitive functions, positively influencing perception, motor skills, attention, and memory, according to studies such as those conducted by Gurtubay et al. (2004) and Gross et al. (2005). Current results emphasize that listening to sounds at 40 Hz, known as binaural beats (BB), can effectively enhance attention, as demonstrated by

Englebregt et al. (2021). Gamma stimulation through BB has also been shown to promote increased divergent thinking, suggesting an increase in cognitive flexibility. This targeted stimulation of gamma waves emerges as a promising opportunity to enhance a range of cognitive processes, including increased attention, accurate perception, and memory enhancement, as highlighted by previous research (Negara et al., 2021). These findings reinforce the hypothesis that the targeted use of 40 Hz sound frequencies may represent an effective strategy to modulate gamma brainwaves and enhance cognitive abilities, opening new perspectives in the field of sound neurostimulation.

4. Flow State in Learning Processes

Flow can be defined as the "feeling of complete engagement in life, an indispensable state of consciousness for self-realization" (Csíkszentmihályi, 1999). In this perspective, having good self-awareness during the execution of a task is directly linked to the lived experience being of quality, leading to the acquisition of lasting skills that can be generalized to broader contexts. This state is present when an individual experiences a balance between the challenges presented and their perceived abilities. It is recognized that optimal and moderate challenges can enhance the flow experience, within which the individual will experience an ideal level of activation in response to the stimuli presented (Wang et al., 2020).

This state of activation is associated with a deep, effortless concentration, in which individuals are fully immersed in the activity at hand. Consequently, this state creates an opportunity to fully enjoy experiences and make the present moment more satisfying, simultaneously building greater self-confidence. This, in turn, allows the development of specific skills and significant contributions to the development of cross-functional and functional competencies. Being in the flow state allows individuals to achieve optimal performance in a specific task. This activation, which can occur in various contexts, can then be generalized to tasks of various natures.

Within learning environments, individuals experience themselves and put their skills to the test in the face of various stimuli. Learning thus becomes a dynamic phenomenon, activating mechanisms for the acquisition and retention of knowledge, proving challenging and responsive to various individual activation processes. In this complex process, personality traits, the sense of immersion in experiences, and behavioral processes interact with the environment, shaping the experiences of information acquisition and determining their characteristics in knowledge assimilation (Tian et al., 2021).

In this complex framework, it has emerged that the flow state in learning processes plays an important role (Wang et al., 2020) as it supports the activation of the individual in the face of challenging tasks, creating an immersive experience that forms the basis for the acquisition of quality information.

5. Conclusions

In light of what emerged in this contribution, it is hoped to redefine the role of learning contexts through the use of environments that allow reaching a state of activation in which the individual can experience oneself and put one's skills into play. To achieve this, an AI software is intended to be used, through which the provided neurosensory experiences enable the person to balance between the difficulty level of

a task and the level of their own skills, to the extent that the task is challenging but not stressful, placing the individual in a state of Flow.

The attainment of this state is characterized by a close mind-body connection in which there is a fusion of thought and action. This contribution aims to propose the use of multisensory environments as facilitators for achieving this state, specifically through a synergy between light and acoustic stimulation.

The training of this pioneering software involves a meticulous process, where the system learns to interpret and respond to a wide range of sensory stimuli. Every detail, from sounds to smells, from temperature to brightness, is carefully evaluated and adapted to create an environment that is not only functional for cognitive enhancement but also empathetic and inclusive, to take the first steps towards a sensitization process to disability.

Following the subject's responses, the software will be able, from time to time, to modify the intensity and type of stimulation in order to define a learning environment that supports cognitive development and the acquisition and implementation of skills.

Indeed, through constant feedback from users and regular updates, the software improves and provides increasingly targeted and personalized solutions. The goal is to create a space that reflects individual needs, where technology not only simplifies daily life but also contributes to improving overall well-being.

Following an analysis of the user profile, an intervention protocol will be developed, defined as the result of the outcomes of individual tests that will assess the subject's state of activation, attention levels, and brain activation. The results of each intervention, which will serve as training material for the software, will be subject to evaluations on dichotomous variables and qualifiers that will allow the collection of data, subsequently stored in a dataset, to create a profile on the individual case study but at the same time contribute to overall assessments to enrich and complete the nature of general data.

Within the application, Machine Learning algorithms are indeed implemented for data processing and the creation of core sets related to the categories of interest. The integration of an AI conversational agent allows generating reports tailored to specific skills, taking into account the different professional profiles of operators and fields of intervention.

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