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Subliminal Training Techniques for Cognitive, Emotional and Behavioural Balance. The role of Emerging Technologies

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Abstract. Traditionally, metacognition & higher mental abilities are thought to be exclusively linked to consciousness. However, a growing number of researchers support the idea that nonconscious processes may hold the keys to higher forms of intelligence. Subliminal messages expose individuals to visual or/and auditory stimuli below the threshold of conscious perception. The current review aims to explore the effectiveness of subliminal cues on fundamental aspects of metacognition such as higher cognitive and emotional meta-abilities, affective and behavioral regulation, and academic achievement. In this context, we search for and classify the existing subliminal training techniques, while evaluating the usability of ICTs such as artificial intelligence, virtual reality, mobile apps, steam and software in subliminal learning and training. The results of this review revealed that subliminal techniques improve all those aspects that assure metacognitive improvements in terms of self- & emotional regulation, higher mental abilities, and behavioral modification. Subliminal cues lower people's shields and update filtering mechanisms enabling people to focus on positive rather than negative interpretations. Subliminal techniques are under the umbrella of metacognitive strategies since they can be used consciously to increase self-regulation capacity as well as expand the horizons of consciousness. Subliminal teaching techniques can be used by teachers and parents in general and special education to instill higher-level needs & motives, accelerate students' performance, reduce gender stereotypes and unfold students' existing but underdeveloped abilities. Therapists can also utilize these methods to help patients with phobia, anxiety and depression to overcome fear. Subliminal techniques can be also utilized as a strategy by leaders, mentors, and employees to build trust, inspire and provide humanity with innovative ideas. ICTs provide the ideal environment for implementing subliminal training. However, more research is needed.

Keywords. Metacognition, Consciousness, Subconsciousness, Automatic self-regulation, intuition training, behavioral change, subliminal teaching techniques, learning performance, emotional regulation, subliminal perception, motivations, mobiles apps, artificial intelligence, ste(a)m, virtual reality, intelligent tutoring systems, subliminal learning, positive thinking

1. Introduction

As humans, we generally have the feeling that we decide what we want and what we do. Our behaviors seem to originate in our conscious decisions to pursue desired outcomes, or goals. Recent discoveries, though, challenge this causal status of conscious will. They

demonstrate that under some conditions, actions are initiated even though we are unconscious of the goals to be attained or their motivating effect on our behavior (Custers & Aarts, 2010).

The scientific literature debating themes on consciousness is huge. Contributing scientists who come from different disciplines have led to an increase in knowledge about consciousness, although it is difficult to reach a well-accepted definition (Sattin et al., 2021). Most researchers agree that conscious thought processes are intentional, controllable, consumptive of limited processing resources, and accessible (Bargh & Morsella, 2008). The human capacity to keep information active on a conscious level is quite limited. For instance, studies report that working memory can hold seven (plus or minus two) pieces of information active at a given moment (Miller, Galanter & Pribram, 1960; Cowan, 2001). Other studies mention that human conscious attention has a bandwidth of only 40 bit/s, whereas the visual perception system has a bandwidth of 10 M bit/s (Zhu, Carpenter & Zeng, 2022). Multiple stimuli compete for selection demanding a place in the limited field of conscious perception (Chun, Golomb & Turk-Browne, 2011).

Metacognition is considered a concept closely related to consciousness (Drigas & Pappas, 2017). Drigas and Mitsea (2020, 2021) define Metacognition as the *set of regulatory meta-abilities and meta-skills that are consciously applied aiming at the smooth operation of the cognitive & psychophysiological mechanism as a means of achieving functional capability, self-efficacy, independent living & life satisfaction. Metacognition involves individuals' ability to observe, regulate and adapt their internal cognitive processes, recognize the difference between functional and dysfunctional states of mind and consciously choose those states that awaken the full range of their abilities and identity.* Metacognition refers also to the consciousness people have about their abilities, skills, and strategies as well as the flexibility to utilize their mental powers strategically to achieve higher goals. Metacognition provides people the unique ability to have supervision and awareness of their existence, to seek the reasons for their behaviors, to wonder about themselves, to search for self-explanations, and self-understanding (Drigas & Mitsea 2020, 2021; Mitsea & Drigas, 2019). However, metacognition which represents the conscious mind is driven mostly by non-conscious factors which may make metacognition unhelpful (Norman, 2020).

The unconscious mind is still viewed by many scientists as the shadow of the conscious mind, though there now exists substantial evidence that the unconscious is no less flexible, complex, controlling, deliberative or action-oriented than is its counterpart. Because subliminal-strength stimuli are relatively weak and of low intensity, this does not mean that the mental processes they drive are necessarily minimal and unsophisticated. On the contrary, actions of the subconscious mind precede the arrival of a conscious mind—that action precedes reflection (Bargh & Morsella, 2008).

Recent experimental studies using visual stimuli have led to the surprising conclusion that top-down control mechanisms can be exerted on non-conscious processing even though individuals have no awareness of what is to be controlled (Dehaene & Naccache, 2006). Automatic forms of psychological and behavioral processes, although unconscious, influence almost everything: desires, judgments, goals, and the way we perceive ourselves as well as others (Bargh, 2006). Even habits can be characterized as learned behaviors that have a high degree of automaticity which means that subjects have less conscious awareness (Orbell & Verplanken, 2010). Studies demonstrate that various disorders, such as panic disorder, are associated with abnormal processing of subliminal stimuli (Baroni et al., 2021). Whalen et al. (1998) found that masked presentation of fearful faces increased amygdala activity, the center of emotions.

According to Cooper & Cooper (2002) stimuli that are presented beyond awareness affect persons' motivational states. In other words, subliminal cues activate the brain mechanisms that are responsible for needs satisfaction which play a fundamental role in human behavior. Maslow's hierarchy of needs (1943) supports the idea that needs satisfaction plays a basic role in human existence because needs motivate humans to set higher goals, change perspective, modify behavior, and improve performance. Thus, subliminal messages have the power to instill higher motives which in turn will be transformed into positive behaviors.

Recent studies associated non-conscious mechanisms with higher mental processes such as various control processes as well as working memory (Hassin, 2013). Scientists agree that a sign of expertise and mastery is considered the execution of skills without conscious awareness (Bargh & Morsella, 2008; Drigas & Mitsea, 2021; 2022). Although most people agree that learning requires conscious awareness, the research reveals that subliminal learning maybe holds the keys to higher forms of intelligence. Subliminal learning can occur because of exposure to a subliminal stimulus, without conscious attention. Nonetheless, subliminal learning is far from being passive and requires high-level processing & attentional processes (Seitz & Watanabe, 2003).

The pioneers of unconscious aspects of human behavior were among others, Freud and Jung. According to Carl Jung (1964), certain events of which we have not consciously taken note, have remained below the threshold of consciousness. Although they have happened, they have been absorbed subliminally. These subliminal aspects of everything that happens to individuals may seem to play very little part in their daily lives. However, they are the almost invisible roots of their conscious thoughts.

Subliminal stimuli are signals below the absolute threshold level of human conscious perception, which means that people are unable to consciously identify them even if they look for them (Elgendi et al., 2018). However, it is important to outline that there is a debate about the limits of human perception with many researchers pointing out that the subliminal threshold can vary from individual to individual, and in the same person from moment to moment (Pratkanis & Greenwald, 1988).

Although the subliminal messages in a narrow sense refer to the messages within a certain range beyond the sensory threshold, they include also different kinds of hidden messages, such as hidden patterns, hidden symbols leading to associations, and difficult-to-perceive background sounds (Bu & Zheng, 2019).

Studies have already shown that the ability to respond to subconscious eye cues typically starts to emerge during infancy around the age of seven months providing a great opportunity for children to early develop social interactive skills (Jessen & Grossmann, 2014).

The methods and the results emerging from studies regarding subconscious reprogramming are increasingly being used in social and health sciences, including advertising, human-computer interactions, and political campaigns (Elgendi et al., 2018).

The subliminal message design includes the type (text, image or audio), aptitude (positive, neutral and negative) and content of the subliminal message based on psychological experiments and according to the course purpose (knowledge imparting, ability training, etc.), demographic characteristics (e.g. gender, age, education background, occupation, marital status and personality) of the course object, teaching conditions (multimedia courseware, teaching video and audio, and the like) (Bu & Zheng, 2019).

Most user support in software applications is administered in an "overt" manner, which means that is readily perceptible and requires a user to think about the information via conscious processing. However, overt help systems also cause task disruption. For instance, in many cases,

users stop what they are doing to think about the steps required to solve a given problem. Recent Human-Computer Interaction (HCI) research outlines the benefits of *subliminal software support* in reducing cognitive processing loads compared to traditional learning software applications. Computers, for instance, are ideal for the presentation of subliminal stimuli, because subliminal cues need to be presented both briefly and quickly, and computers are great at this kind of behavior. In addition, nowadays millions of people spend their entire working lives staring at a screen (Kelly, 2011). Early studies have already shown that subliminal training via computers and wearable devices can improve cognitive abilities as well as learning performance (Wallace, 1991; Corey et al., 2003). Mobiles also provide a clear opportunity for mobile behavior change interventions using subliminal priming (Pinder et al., 2015). Video games provide the optimum environment for subliminal learning. In addition, subliminal training can also support reinforcement learning, a training method based on rewarding desired behaviors and/or punishing undesired ones. Subliminal guidance can unconsciously guide players' behaviors or urge them to follow alternative strategies, while they feel that they have the freedom to choose. It also prepares the player through practice, without being aware of a greater challenge. Subliminal messages can also facilitate players to enter the flow zone. However, these digital environments are not easy to be properly designed (Quesada Mora et al., 2017; Seitz & Watanabe, 2003).

2. Method

The purpose of the current review study is to shed light on the benefits of subliminal messages on cognitive and metacognitive abilities, affective and behavioral regulation as well as learning and academic achievement. Moreover, we investigate the usability of ICTs in subliminal training. We systematically searched clinical and technical databases including Scholar Google, Pubmed, IEEE Xplore, Scopus, Science Direct following a comprehensive search strategy with main research terms the following: subliminal cues, visual cues, auditory cues, masked stimuli, subliminal stimulation, unconscious perception. Priority was given to experimental research studies. Regarding ICTs, we explored the role of mobile apps, virtual reality, intelligent tutoring systems and software. When it comes to research limitations, we can mention the lack of experimental studies evaluating the effectiveness of subliminal training via digital technologies.

3. Results

3.1 Subliminal Techniques & Strategies

Subthreshold Stimuli: Stimuli are provided at intensity levels, which are too weak for subjects to identify. Visual patterns can be presented at very low levels of brightness, or with very low contrast, whereas auditory patterns at a very low signal-to-noise ratio (Pratkanis & Greenwald, 1988).

Masked stimuli: Masking refers to the reduction of the intensity of one stimulus or change in perception of this stimulus because of the simultaneous application of two or more stimuli. Visual information masking can take various forms, namely, brightness masking, texture masking, frequency masking, time masking, and color masking (Bu & Zheng, 2019).

Visual stimuli are obscured from detection using a variety of methods: by presenting a (masking) bright flash just before or after a briefly presented pattern. Pattern Masking refers to the presentation of a masker stimulus just after a target stimulus aiming to reduce the visibility of the target stimulus (Siegel et al., 2017). Metaccontrast masking or backward masking refers to the suppression of the visibility of a briefly flashed target stimulus by a similarly brief and spatially adjacent mask stimulus that follows the target in time at varying stimulus onset

asynchronies (Breitmeyer et al., 2008). A backward masking technique is central masking in which the brief masked pattern and the rapidly following pattern mask are displayed to nondominant and dominant eyes, respectively (Pratkanis & Greenwald, 1988).

Auditory information masking can be divided into two types, i.e. time-domain masking and frequency-domain masking (Bu & Zheng, 2019). The auditory subliminal message can be produced by speeding up the rate at which it was initially recorded until it could not be consciously understood. The message can be mixed with a normal music recording (Kaser, 1993). In the backward masking technique, messages may be formed by hiding a low-pitched sound behind a high sound. For instance, it is stated that a voice saying “Good teenagers, take off your clothes” is heard in a scene of the cartoon movie Aladdin produced by Disney. Backmasking appears before us as a reverse recording of a message (Arslan, Ozdemir & Kuscü, 2017).

Subliminal Priming: Subliminal stimuli can also be used as ‘primers’ that is, influencing future conscious action without awareness of the prime (Brooks et al., 2012). There are several types of primes such as semantic priming, visual priming, response priming, perceptual and conceptual priming, positive and negative priming, associative and context priming & olfactory priming (Elgendi et al., 2021).

Unattended stimuli: A range of techniques can be employed to distract attention from a given stimulus. For auditory stimuli, a commonly used research procedure is to give the participant the task of “**shadowing**” (repeating aloud) a verbal message presented to one ear, which forces the subject to ignore a verbal message presented to the other ear. Regarding vision, an unattended stimulus can be provided (a) peripherally in the visual field when the subject has another task that requires attention to a different location, (b) centrally in the visual field during a task that requires cognitive activity incompatible with analyzing the unattended one, and (c) as an embedded figure that is unlikely to be segregated from its figural context (Pratkanis & Greenwald, 1988).

Figurally transformed stimuli: A variety of techniques such as presenting a picture or word that is blurred to the point of unrecognizability, decomposing a pattern, and rearranging the pieces, filtering higher audio frequencies from speech, or reversing speech. Contrary to unattended stimuli techniques, stimuli in this category are unidentifiable even when focal attention is directed to them (Pratkanis & Greenwald, 1988).

Subliminal Positive Affirmations: Subliminal positive affirmations embedded in a piece of relaxing music can facilitate the behavioral change toward an intended goal (Chakalis & Lowe, 1992).

Subliminal Framing: For example, subliminal goal priming can influence implicit goals of “obtaining the positive consequence (i.e., positive framing)” or “avoiding the negative consequence (i.e., negative framing)” (Legal et al., 2012).

Left eye & right ear subliminal training: Research has already shown that the left hemisphere controls the leading right eye, whereas the left controls the right hemisphere, which is responsible for various nonconscious processes as well as for negative feelings (Goodarzi et al., 2015; Kostandov & Arzumanov, 1986). Research also indicates that when two different speech stimuli are simultaneously presented to both ears, listeners report stimuli more correctly from the right ear than the left, indicating separate observations of left and right-ear responses to acoustic stimuli (Tanaka et al., 2021).

Subliminal Exposure to Cine Films and Animation: Tyrer, Horn & Lee (1978) investigated a new intervention for phobia. Patients with phobia were shown a phobic film at such a low level of illumination that nothing could be seen on the screen. This was achieved by

putting filters in front of the projector and by increasing the background illumination of the screen. The level of illumination was chosen beforehand so that observers all agreed that nothing could be seen on the screen during the viewing of the film and this level was maintained throughout the presentation of the agoraphobic film in the subliminal group. The subliminal group showed significantly greater improvement in phobic fears, avoidance, and overall improvement than did the control group. **Chant music in the background while watching the film** can be used to further produce a **meditative, relaxing state** (Hilton, 2006). **25th frame technique:** While forming film frames, 24 frames are shown per second. In this way, the human eye watches a flowing image instead of intermittent frames. Control intervals (i.e. 25th frame) are left blank to ensure the arrangement of the film frames. In this subliminal method, it is possible to embed any desired image in this blank 25th frame (Arslan, Ozdemir & Kuscu, 2017).

Subconscious symbols: They are symbols usually identified with an ideology or belief (Arslan et al. 2017). A mandala is a spiritual and ritual symbol representing the Self within the universe. Mandalas are employed for training focused attention, for establishing a sacred space, and as an aid for meditation and trance instruction. Through its balanced visual elements symbolizing unity and harmony, mandalas form a symbolic scheme that can help one to access progressively deeper levels of the unconscious (Dauden Roquet & Sas, 2019). **Rice Writing** is an ancient art that requires writing a word or name on a single grain of rice. Rice symbolizes the means that transfer one's written message.

Subliminal messages during Sleep Learning Methods: Hypnopaedia is the learning process that takes place during sleep or the ability to learn while sleeping. This form of learning depends also on subliminal message training through which learning gets accelerated, the accuracy in data processing rises, unsolved problems get solved, and entrepreneurial ideas come to light (Kapsi et al., 2021).

Prayer & Meditation Practices: Prayer and meditation engage various subliminal training practices such as **chanting**, and **subliminal affirmations**. Experiments conducted by Strick et al. (2012) revealed that people after meditation subjects increase the use of subliminally primed words indicating better access to unconscious processes. **Prayer Wheel** is a cylindrical wheel on a spindle made from metal, wood, stone, leather, or coarse cotton, widely used in Tibet. Within the prayer wheel cylinder is a tightly wound roll of printed mantras, that is invocations containing subliminal messages with symbolic value that invoke compassion (Brox, 2022).

Fairy tales & Mythology: Fairy tales contain various symbols and subliminal messages. Ruini et al. (2014) found in their study that fairy tales can increase personal growth, and self-acceptance, and enhance the sense of appreciation of life and personal strengths, together with lower levels of anxiety.

Subliminal messages via other senses: Li et al. (2008) examined whether hedonic content of undetectable odors would alter social likeability judgments of human faces. Pleasant, neutral, and unpleasant odorants were presented at concentrations below participant-specific detection thresholds in a total of 39 participants. It was revealed that subliminal odors can influence social likeability judgments and autonomic responses in a valence-consistent manner.

The Impact of Subliminal Messages on Cognition

Memory performance

Levy (1996) designed an intervention intending to examine how subliminal positive messages would improve memory performance and memory self-efficacy. Ninety participants were randomly assigned to one of two implicit self-stereotyping conditions in which a computer subliminally presented words related either to a senile or a wise image of old age. The memory

tests were administered before and after the intervention assessing a variety of memory types (i.e. e immediate recall, learned recall, and delayed recall tasks, photo recall tasks, and metamemory tasks. This research demonstrated that subliminally activated stereotypes can alter judgments about oneself and can change cognitive performance.

Chakalis & Lowe (1992) evaluated the effect of subliminally embedded auditory material on short-term recall. Sixty volunteer subjects undertook a face-name-occupation memory test before and after a 15-minute. intervention. They were randomly assigned into a control group and two experimental groups under the following conditions: (1) no sound, (2) supraliminal presentation of relaxing music, and (3) subliminal presentation of memory-improvement positive affirmations embedded in relaxing music. After the intervention, only the subliminal group significantly improved their performance in the recall of names.

Wuethrich et al. (2018) investigated whether subliminal cues can create spatial episodic memories. Participants were presented with subliminal scenes, which displayed objects at certain locations for participants to form unconscious object-in-space memories. During the test phase, participants performed a forced-choice task that required them to place an object in one of two highlighted scene locations and their eye movements were recorded. The results revealed that participants remembered object locations unconsciously.

Attention:

McCormick (1997) investigated the role of awareness in orienting visual attention. Subliminal or supraliminal cues were presented to 16 participants. It was revealed faster orienting to the target when the cue and target locations matched were seen for subliminal cues. The results also support the hypothesis that attention can be captured by a stimulus event of which observers have no awareness. Mulckhuysen, Talsma & Theeuwes (2007) confirmed also that subliminal cues can exogenously capture attention. According to Baumeister et al. (2015) subliminal cueing not only can capture and orient attention but can also reduce cognitive load reducing the waste of attentional resources.

Ansorge, Kiss & Eimer (2009) utilized event-related brain potentials (ERPs) and behavioral measures to evaluate whether subliminal visual stimuli can capture attention in a goal-dependent manner. Participants looked for visual targets characterized by a specific color. Search displays functioned as metacontrast masks for preceding cue displays that included one cue in the target color. Although this target-color cue was spatially uninformative, it produced behavioral spatial cueing effects and triggered an ERP correlate of attentional selection. These results demonstrate that subliminal cues not only capture attention but also engage top-down control processes.

Visuospatial skills: Kaser (1993) investigate what effect an auditory subliminal message, produced by speeding up the rate at which it was recorded, would have upon the imagery of a group of college students. The auditory subliminal message was produced by speeding up a message that was sung until it could not be consciously understood. This message was mixed with a normal music recording and played to nine subjects in the experimental group while nine subjects in the control group heard the normal music recording without the subliminal message. The results indicated that auditory subliminal messages did affect the imagery of the subjects in the experimental group.

Perception

Blanchfield, Hardy and Marcora (2014) exposed 13 athletes to positive subliminal cues, such as action-related words including 'go', and 'energy' or were shown happy faces as they cycled to exhaustion. The words and faces appeared on the digital screen for less than 0.02 seconds and were masked by other visual stimuli to be unidentifiable to the subjects'

consciousness. The results showed that subliminal positive cues improved athletes' endurance performance. Subliminal messages altered subjects' perception of how effort is required as well as the sense of fatigue. Subjects were more motivated to reach the highest effort. Most important, subliminal cues regulated subjects' conscious behavior to transcend the boundaries they had imposed upon themselves.

Levi et al. (2014) investigated whether positive subliminal cues would alter older people's beliefs about themselves. One hundred individuals were randomly assigned to an implicit or explicit positive stereotype group. The results showed that the subliminal intervention group altered negative beliefs about themselves. They developed a positive self-perception which in turn helped them to improve their physical functions and well-being.

Era, Candidi & Aglioti (2015) utilized a forward/backward masking procedure to investigate how subliminally positive and negative, arousal-matched, emotional or neutral primes influence the explicit evaluation of perceived beauty and emotion evoked by abstract and body images. The results showed that subliminal primes altered subjects' subjective evaluations. Interestingly, it was revealed that subliminal primes that evoke negative emotions lead to positive aesthetic evaluations.

Decision Making

Ruch, Züst & Henke (2016) examined whether subliminal messages might affect delayed decision-making especially when messages contain several pieces of novel information that must be relationally bound in long-term memory. Two experiments were conducted. In experiment 1, they tested whether subliminal presentations of face-occupation pairs would guide later conscious decisions about the income of the same faces. In experiment 2, subliminal presentation of the vocabulary of a foreign language enabled participants to later decide whether these foreign words are presented with correct or incorrect translations. The results showed that subliminal verbal and nonverbal item pairs influenced participants' conscious, deliberate decisions. The researchers also provide unprecedented evidence of considerable longevity of subliminal effects on intentional behavior such as decision-making.

Executive functions

Intentional inhibitory control has traditionally been linked with a conscious form of voluntary self-control; thus it requires conscious effort and awareness. Parkinson & Haggard (2014) investigated whether subliminal primes could bias 'free' choice to act or inhibit action. The researchers used a modified Go/No-Go paradigm in which Go, No-Go, or Free Choice targets were preceded by masked primes. The results showed that voluntary inhibition control can be unconsciously influenced by subliminal cues.

Traditionally, higher cognitive control functions are thought to require consciousness. The prefrontal cortex is believed to be one of the most important parts of the network responsible for conscious control processes. Lau & Passingham (2007) investigated whether unconscious information can influence the cognitive control mechanism in the human prefrontal cortex. Participants were given instructions to prepare either a phonological or a semantic judgment task. However, in some trials, they were primed to do the 'wrong' task. In other words, the prime was incongruent with the instruction. When the prime was incongruent with the instruction, the researchers observed activity in the mid-dorsolateral prefrontal cortex, possibly because the brain recognized the conflict. The researchers concluded that the cognitive control system in the prefrontal is not exclusively driven by conscious information, but also by unconscious information.

Van Gaal et al. (2010) used functional magnetic resonance imaging to investigate to what extent unconscious "no-go" stimuli can reach cortical areas involved in inhibitory control,

particularly the inferior frontal cortex. Participants performed a go/no-go task that included conscious (weakly masked) no-go trials, unconscious (strongly masked) no-go trials, as well as go trials. The results showed that unconscious no-go stimulus also can activate prefrontal control networks.

The impact of Subliminal Messages on Emotions & Behavior

Siegel et al. (2017) investigated the neural activity during subliminal exposure to phobic stimuli. Twenty-one spider-phobic and 21 control participants viewed stimuli under the following three conditions: (a) exposure to masked images of spiders, (b) visible exposure to spiders and (c) masked images of flowers. The results showed that exposure to phobic stimuli without conscious awareness can be a more efficient intervention strategy to deal with phobias compared to conscious exposure. Neural activity data of phobic subjects demonstrated that subliminal exposure activated brain areas responsible for fear processing and regulation minimizing the conscious experience of fear.

Parkinson et al. (2017) explored whether the subliminal perception of emotional faces can modulate volitional choices to act or inhibit action. Utilizing a novel version of the Go/No Go paradigm, participants were asked to make speeded button-press responses to Go targets, inhibit responses to NoGo targets and make free choices for choice targets. Before each target, the participants were presented with emotional faces, backward masked. The results showed that subliminal angry faces made participants more likely to withhold the action.

Monahan, Murphy & Zajonc (2000) examined whether repeated subliminal exposure could alter mood and emotions into more positive ones. Participants were presented with subliminal stimuli. Immediately following the exposure phase, the participants were asked to report their current mood by selecting among five pictures of a face that varied from neutral to smiling. The results showed that subjects tended to select significantly more positive facial expressions as representing their current after subliminal exposure.

Pottratz et al. (2021) investigated the effects of a music video with embedded subliminal primes on affective states during and immediately after an exercise bout. Findings indicated that subliminal primes elicited more positively valenced affect during exercise and a more enjoyable exercise experience. The authors concluded that subliminal primes can elicit more positive changes in affective responses compared with the absence of subliminal cues.

Ota & Nakano (2021) exposed subjects to a subliminal face of their face. It was found activation in the ventral tegmental area, is a central component of the dopamine reward pathway in case of subliminal presentations. These results indicate that subliminal messages involve the dopamine reward pathway which is responsible for motivation and emotional manipulation.

Legal et al. (2012) investigated the effect of subliminal goal priming on the processing of a persuasive message. Before reading the message, participants were subliminally primed (or not) with the goal “to trust”. The results indicated that non-conscious activation of the goal “to trust” led participants to evaluate more positively the message and develop more positive behaviors. The authors hypothesized that motivation “to trust” maybe works as a filter, leading people to focus only on positive/pros arguments in the message, and lower people's shields.

The Impact of Subliminal Messages on Learning & Academic Achievement

Lowery et al. (2006) investigated the effects of subliminal priming on academic performance. They subliminally exposed 70 undergraduate students to words either related or unrelated to intelligence and afterward, they assessed students' performance on two exams. The intelligence primes were *intelligent, smart, brilliant, bright, talented, sharp, clever, brainy,*

gifted, educated, genius, and learned. The results showed that subjects that saw the intelligence words performed better.

Chalfoun and Frasson (2010; 2011) conducted two studies with subliminal teaching techniques aiming to improve learners' performance in a tutoring system. In the latest study, the researchers used physiological sensors. The researchers presented subliminal positive and negative cues. The results indicated that positive subliminal cues caused almost a 10% improvement in learners' performance in a logic-based problem-solving task. It also revealed a strong influence on reasoning skills and logical decision-making.

Ariam and Siller (1982) made the hypothesis that 4-msec tachistoscopic exposure to subliminal messages would result in higher grades on the final examination in mathematics. 72 Israeli 10th graders were randomly assigned to 4 treatment groups and tachistoscopically presented with subliminal exposures of 1 of 4 of the following verbal stimuli: 'mommy and i are one' (2 versions); 'my teacher and I, we are one'; and a neutral stimulus 'people are walking in the street'. The intervention covered 6 weeks (4 times per week). Achievement tests administered revealed that participants exposed to subliminal messages exhibited significantly higher scores in mathematics.

Fleming, J. (2019) examined the effectiveness of commercial subliminal audio aids along with a method of automatic delivery of said messages on academic performance in a sample of students. 324 students were divided into two groups, the experimental and the control group. The experimental group was asked to use a subliminal audio CD for "accelerated learning" as a morning alarm during their first academic year. After 8 weeks, the experimental group performed better in terms of academic performance.

Bryant-Tuckett & Silverman (1984) investigated the effects of subliminal stimulation on the academic performance of emotionally handicapped students. The subliminal positive affirmation for the experimental group was the phrase, "Mommy and I are one", whereas the control group was exposed to the phrase, "People are walking". Results showed that the experimental group manifested significantly greater improvement on the achievement tests than did the controls. On 5 of 6 secondary variables—arithmetic achievement, self-concept, the handing in of homework assignments, independent classroom functioning, and self-imposed limits on TV viewing—the experimental group showed better adaptive functioning.

The Usability of ICTs in Subliminal Training Mobile Applications

Zhu, Carpenter & Zeng (2022) built a restaurant table reservation mobile app that asks users for their identity information. The subliminal warning message, "Privacy," was shown once for 50 ms, just in time as they typed in their personal information. Thirty participants were in the experimental condition and another thirty participants were in the control condition (no warnings). The results revealed that participants in the subliminal warning condition disclosed less personal information than those in the control condition.

Păsărelu, Andersson & Dobrea (2020) reviewed the Apps based on hypnosis appropriate for attention deficits. These apps were presented as audio contents in which relaxation suggestions are induced on a music background, or the participant receives several positive affirmations or subliminal messages aimed to improve performance, without relaxation suggestions and music. An example of subliminal message is: "Mommy and I are one, every day I am better and better, every day I am more confident, I am loved, I am smart, I am worthy, I am confident, I have confidence in me, I am worthy to be that which I want to be, every day I have more confidence".

Pinder et al. (2015; 2017) presented a novel approach to exploring the presentation of subliminal stimuli on smartphones aiming to activate nonconscious goals to make the desired behavior more likely to be performed. They presented three explorations of the technique: a technical feasibility study, and two participant studies. A pilot study (n=34) explored subliminal goal priming, while a semi-controlled study (n=101) explored the immediate effect of subliminal priming on 3 different types of stimuli. They found that although subliminal priming is technically possible on smartphones, there is limited evidence regarding its effectiveness.

Roquet and Sas (2019) searched for the most popular mobile applications that utilize the mandalas technique and investigated their effect on mental health. The authors concluded that these applications can bring significant benefits to attention and self-regulation. However, more attention should be given to the philosophy and the purpose of this practice is taken seriously in software design.

Digital Games

Larsen (2013) initialized a computer game design framework where learning and play experience could be enhanced by using subliminal cues in-game tutorials. A cognitive experiment and player experience research was used to explore how to subliminally influence decision-making within a 3D game environment. Results indicated that participants showed greater ability for intuitive responses (rapid response times when solving a given task). They also had a higher-than-average experience level with playing computer games.

Maureira et al. (2015) deployed visual affect priming in the environment of a horror computer game while maintaining strict standards regarding subliminal thresholds. Fear-inducing images were shown repeatedly to players (N=60) during 5-minute playing sessions, using sandwich masking and a prime duration of 33.3 ms. Three types of images were compared to an empty control image: text, faces and spiders. The results showed an increase in relaxation for players who were primed with face images.

Augmented Reality Glasses

Blanchfield, Hardy & Marcora (2014) conducted two experiments investigating the effects of subliminal priming with visual cues related to affect and action on the perception of effort and endurance performance. The researchers found a strong influence of subliminal cues on performance. They also suggested that non-conscious visual cues can be used as a performance-enhancing strategy during training by using contemporary technology such as smart glasses. The use of smart glasses as a subliminal training tool would give a solution to the debate about the ethical considerations since the users consciously and freely choose to follow a training intervention according to their needs and goals. It would be interesting to examine the subliminal priming effects when individuals are aware that they are being subliminally primed as well as to examine whether these effects remain after training.

Spatial Augmented Reality

Baumaster et al. (2015) conducted two experiments to evaluate subliminal cueing techniques in spatial augmented reality (SAR). The researchers explored whether helpful subliminal cues could lead to faster reaction time. The results showed that the application of subliminal cueing facilitated procedural task performance in a SAR environment.

Artificial Intelligence & 3D subliminally teaching Intelligent Tutoring Systems

Learning in virtual worlds has taken a very important part in Human-Computer Interfaces. Recent studies investigate whether Intelligent Tutoring systems can support subconscious learning to accelerate learning performance (Chalfoun & Frasson, 2008; 2011).

Chalfoun & Frasson (2009) investigated the optimal emotional state of learners when using a subliminal teaching intelligent tutoring system. They stated two research questions.

First, in learning to solve a problem in a 3D virtual system, whether there is a significant emotional state in which the best learners are that sets them apart from the rest. Second, in answering what significant relationship we can establish between learners' emotional state and subliminal projections. The experiment used precise and timed subliminal projections in a 3D intelligent tutoring system while monitoring the physiological reactions of the learner. At the same time, they recorded the actions on the screen as well as the facial movements of the learners. A total of 31 healthy volunteers, 16 men and 15 women, took part in the experiment. The results revealed the positive long-term impact of subliminal priming on the entire learning process. Chalfoun & Frasson (2011) provided also compelling evidence for the positive impact of subliminal cues on reasoning and intuitive decision-making in a logic-based problem-solving paradigm in Intelligent Tutoring Systems.

Neurofeedback Interfaces

Hinterberger (2011) presented the 'Sensorium', a neurofeedback environment that allows people to experience signals from subliminal psycho-physiological processes visually and auditorily via a thought translation device. Various (neuro-)physiological rhythms and frequencies were projected simultaneously as soundscapes and "lightsapes" into the environment. A wireless physiological amplifier device transferred signals such as EEG and ECG to a computer for real-time processing via the modified brain-computer interface software "Thought Translation Device" (TTD). The TTD provided signal filtering, parametric orchestral sonification, and light control. In a pilot study, 20 participants have been exposed to their ongoing brain and heart signals while sitting inside the Sensorium, a small room equipped with a speaker and lighting system. Almost all of them reported an increase in contentment, relaxation, happiness, and inner harmony.

Software

Auditory Software: Using auditory software, individuals can record themselves using positive affirmations or other self-hypnosis techniques. Audacity, for instance, is a free, open-source, cross-platform audio software that provides users the opportunity to make their subliminal recordings (Barrios & Almanzar, 2014).

Ste(a)m Activities & 3D Printing: Ste(a)m activities can incorporate various activities that engaged subliminal messages (Wynn & Harris, 2013). For instance, sacred geometry ascribes symbolic and subliminal meanings to certain geometric shapes and certain geometric proportions. Steam activities regarding the subliminal meaning of shapes could be a beneficial activity. Steam practices to explore ancient architectures using augmented reality and 3D Printing with GeoGebra can also help students to be engaged with subliminal learning.

Conclusions

The current review aimed to explore the effectiveness of subliminal cues on fundamental aspects of metacognition such as higher cognitive and emotional meta-abilities, affective and behavioral regulation, and academic achievement. In this context, we searched for and classified the existing subliminal training techniques, while evaluating the usability of ICTs such as virtual reality, artificial intelligence, mobile apps, intelligent tutoring systems, steam, 3d printing and software in subliminal learning and training. The results of this review revealed that subliminal techniques improve all those aspects that assure metacognitive improvements in terms of self- & emotional regulation, higher mental abilities, and behavioral modification.

Specifically, it was revealed that subliminal messages have the following **positive influences**:

Cognition

- **Memory improvements** (better recall, photo recall, improved short-term memory, better metamemory & memory self-efficacy).
- **Attentional improvements** (attentional flexibility, improved attentional control and better saving of attentional resources).
- **Imagery & Visuospatial skills**
- **Less Mental Fatigue**
- **Logical Decision-Making skills**
- **Objective judgments**
- **Executive Functions** (better inhibition control & cognitive control)
-

Emotions & Behavior

- **Improved Emotional Regulation and motivational manipulation**
- **Minimization of the conscious experience of fear**
- **Positive self-perception**
- **More positive behaviors**
- **Mood improvement**
- **Less defensive attitudes**
- **Adaptive behavior**
- **Fewer self-imposed limits**

Learning

- **Better academic performance**
- **Problem-Solving skills**
- **Reasoning & decision-making skills**
- **Mathematics & Arithmetic skills**
- **Learning Acceleration**
- **Independent classroom functioning**

The incorporation of digital technologies in the education domain is very productive, and successful, facilitates and improves the educational procedures via Mobiles [71-80], various ICTs applications [81-115], AI & STEM [116-128], and games [129-134]. Additionally, the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [135-150] as well as with environmental factors and nutrition [68-70], accelerates and improves more over the educational practices and results.

Moreover, ICTs provide the ideal environment for the implementation of these techniques. Computers, Mobile Apps, Virtual Reality environments, software, and intelligent tutoring systems ensure that stimuli are unnoticed providing a high-quality experience. Results showed that digital subliminal training systems have positive effects in terms of reaction time, positive emotions, stronger motivation, and goal setting. These technologies can provide great opportunities if applied in the educational context, in therapy, and workplace settings. However, more research is needed regarding the effectiveness and the design according to the needs of the participants.

Subliminal cues lower people's shields and update filtering mechanisms enabling people to focus on positive rather than negative interpretations. Subliminal techniques are under the umbrella of metacognitive strategies since they can be used consciously to increase self-

regulation capacity as well as expand the horizons of consciousness. Subliminal teaching techniques can be used by teachers and parents in general and special education to instill higher-level needs & motives, accelerate students' performance and unfold students' existing but underdeveloped abilities. It is not accidental that studies have shown that educators see positively the use of subliminal training in school (Arslan et al., 2015). Therapists can also utilize these methods to help patients with phobia, anxiety, and depression to overcome fear. Subliminal techniques can be also used as a strategy by leaders, therapists, mentors, and employees to build trust, inspire and provide humanity with innovative ideas.

Subliminal teaching techniques can be used in educational, or treatment contexts combined with Digital Technologies in the following ways:

- Creating Movies, Songs, Videos & Animation with subliminal cues
- Fairy Tales & Storytelling
- Mythology & Allegories
- Use of Symbols (mandalas)
- Art (mandalas, optical illusions, rice writing)
- Prayer techniques (chanting, prayer wheels)
- Artificial Intelligence for subliminal training
- Subliminal Messages Apps (mandala coloring, subliminal affirmations listening)
- Digital Games with subliminal messages
- Steam Activities & 3D printing (sacred geometry activities)
- Virtual Reality Environments (Virtual Glasses)
- Software (auditory software for creating subliminal positive affirmations)

Teachers can design their subliminal training strategies according to the student's needs as well as the skills and values that a high consciousness society aims to achieve.

Future research should investigate the use of subliminal training techniques in educational, therapy and workplace settings. In addition, research should be done about the design of appropriate digital subliminal training environments. Finally, it would be interesting to investigate the role of other senses in subliminal multisensory training.

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