MOVEMENTS IN ANALOGIC OR DIGITAL CONTEXT: A CRITICAL COMPARISON

MUOVERSI NEL REALE E NEL DIGITALE: UN CONFRONTO CRITICO

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ABSTRACT

All human activity, including the use of digital media, have an imprint on the human brain. Indeed, the interaction with virtual tools changes cortical activity in the motor or somatosensory cortex and lead to a reduction of hippocampus volume.

Even if, multi-digital environments are associated with faster mental processing of discrete stimulus the analogic experience remained the golden standard because we learn with our body in a end-less stimuli context that only the realty can supply.

Tutte le attività umane, compreso l'uso dei media digitali, hanno effetti sulla rete neurale del cervello. L'interazione con gli strumenti digitali/console modifica l'attività dell corteccia motoria e somato-sensoriale con riduzioni del volume dell'ippocampo.

Anche se le interazioni multi-digitali inducono veloci elaborazioni mentali degli stimoli l'esperienza analogica è la più completa perché noi impariamo attraverso il corpo in un contesto di infiniti stimoli che solo la realtà può fornire.

KEYWORDS

Neuroplasticity, digital media, body image, somato-representation, perception

Neuroplasticità, media digitali, immagine corporea, rappresentazione somatica, percezione

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Introduction

From birth we develop physically and psychologically thanks to external stimuli. In particular, the *bombardment* of stimuli of the environment are the beneficial stress that forces the body and the brain to react in an infinite routine. This interaction between our cells and genes and the environment become fundamental for our development: also, from a social point of view. We experience the stimuli via the sensory ways which *carry inside* information of the external world (exteroception) and/or from our body (interoception) to some specific brain area. Exteroception describes sensory information that comes from the environment around us (e.g. sight, hearing, touch; Latash, 1998) while interoception is the self-perception of our body and includes temperature, pain, itch, muscular/visceral sensations (Craig, 2002). This information derives from different and complementary sensory ways and must be integrated: thus, our brain is forced to interact with and learn from these stimuli that are a representation of the body and environment (Ingold, 2011; Winnicott, 1990) defining the 'magic' phenomenon of interactions known as body-mind (Rowlands, 1999) or in more recent terms Embodied cognition (Gomez Paloma et al., 2016). In particular, the multisensory integration emerges in a no-linear pattern (Hill et al., 2012): we rely on the various sensory modalities to different degrees at different points in the human developmental trajectory, during which the sensory modalities interact in different ways (Bremner et al., 2012). We can affirm that humans learn by doing and through the movement in close relationship with the surrounding environment (Shanks & St. John, 1994). Interactions between the areas of the central nervous system (CNS) and peripheral musculoskeletal structures induce neural network changes (Diamond & Ling, 2019) increasing the nervous connection (i.e. synapses) and becoming a permanent thinking and/or competence (Suzuki, 2008). In brief, the perception is functional for the action whereas the environment must provide sufficient and adequate information to guide the action (Gomez Paloma, 2013).

In point of this, from many years, several researchers, philosophers, psychologists, and physical education teachers moved their interest on this relationship and tried to explain the existing relationship between the subject (as a whole of body and mind) and the surrounding environment (Meinel, 2000).

To stay on the practical level, anticipatively avoiding an obstacle is the consequence of environmental analysis and response selection process (Schmidt & Wrisberg, 1999) which is based on neuronal information transmission and is the foundation of the motor intelligence (i.e. perception of space, time and application of own logic). The external stimulus triggers a logic-cognitive process that, unconsciously, provides an appropriate response towards and into the environment (Mangold, 2020): we can affirm that the logical processes are seen through the adequate movement/motor response.

Bernstein's ideas about motor control, studies on motor development derived from American researchers (Latash, 1998), mirror neurons discoveries (Cattaneo & Rizzolatti, 2009), the relationship between the cerebral nucleus, such as the hypothalamus and the hippocampus, that associates sensations and memories with a specific event and/or stimulus (Suzuki, 2008), the motor and premotor areas (Magrini, 2017) clearly demonstrated that human movement (except for reflexes) is a cognitive process (Lakoff & Johnson, 1999; Lodi et al., 2018). Therefore, the environment is fundamental for the maturation of the CNS: maturation process that is also defined as neuroplasticity (neuro = neurone, plasticity = malleability) as the ability of the brain to change and adapt itself (Friston, 2005).

In fact, after the Pineas Cage event (García-Molina, 2012) and the Merzenich discoveries (Paul et al., 1972) the scientists understood that the brain can efficiently modify itself in accordance with the usage, the habits, and the experiences. In fact, plasticity happens at the network level by altering the synapses between neurons and is therefore called activity-dependent synaptic plasticity. In other words, throughout our lifetime, our brain continuously revises its own wiring. This is a revolutionary change of we consider growth, learning, memory, reasoning, rehabilitation, and capacity conservation. Basically, as reported by Gomez Paloma et al. (2016), a circularity between environmental stimuli and brain adaptation.

These considerations involve that all human activity performed on a regular basis, including use of digital media, social networks, or computerized console, will have an imprint on the human brain: the human cognitive function depends on the activity itself.

Can we hypothesize that the use of digital devices changes our perception of stimulus and then the neuronal networks? If the neuronal network changes, does our way of interoception change? If our motor sensory system changes, does our movement ability in the real environment change?

1. Neuroplasticity due to movements within analogic space

Up to the 1980s scientists and neurologists already knew the concept of neuroplasticity but they thought that it only belonged to early stage of life (Sanai et al., 2011) without other changes or development during adulthood. They considered this process as an obsolete nonmodifiable 'neuronal wiring', whose process would inevitably lead to gradual deterioration (Statsenko et al., 2021).

Today, we know that this was far from the truth. In fact, the brain is considered as a structure, or more likely a *wiring*, which constantly goes through profound changes both in positive and negative directions (Mowery & Garraghty, 2023).

As a leading example, the monkey's hand, like the human hand, is linked to the brain by three main nerves (radial, medial, and ulnar) that connect electric signals to specific areas of the brain. Merzenich et al. (1983) through magnetic resonance imaging, saw the activation of the monkey neuronal network with the light-up of areas of the brain linked to the hand in response to external stimulation. Then, the scientists during his experiment cut the monkey’s medial nerve and the corresponding brain area became inactive. Moreover, he noted something relevant: after some months, brain areas were remapped itself responding to external stimuli lighting up adjacent areas of the hand served either by the radial or by the ulnar nerve. They discovered that the neurons without receiving signals from the medial nerve after a long time responding to signals from other still functioning nerves, highlighting the brain plasticity in reassigned brain areas to different actions to overcome nerve and function lost. The american neurological staff (Merzenich et al., 1983) continued the experiment on monkeys linking two fingers, normally served by different nerves. A successive micro-mapping indicated that the separate neuronal networks that had previously responded to signals from the distinct fingers/nerves were now merged into a single network, responding to signals from what was now in effect one finger. Definitely, the monkey experiments demonstrate that the mature brain rearranges itself in response to external stimuli (Merzenich et al., 1983; Paul et al., 1972). Thus, nowadays is well known that the immature brain constructs and sculpts itself by configuring its neural linkages to make best use of the sensory input received in early life. It is undeniable that our brain guides us and our movement through the environment and constantly modifies itself: thanks to higher and deeper connections between the different brain areas that continue to grow and learn (Mayseless et al., 2023).

Several studies (Albarran et al., 2021; Byl et al., 2002; King et al., 2022) demonstrate that external stimulus, body movements and actions, management of different tasks act as inputs or stressors that lead to a better neuronal network functioning that permit a complete management of several motor tasks: from the simple typing on a computer keyboard to the most complex as a basketball shooting.

An evidence-based neurological concept that became renowned thanks to two famous motto – “Use it or lose it” and “Fires together - Wires together” that recall the crucial role of the experience. Indeed, as mentioned above, Merzenich’s experiments (Merzenich et al., 1983), Bernstein's studies on motor control (Profeta & Turvey, 2018) and Bobath's theory within neurorehabilitation process (Vaughan-Graham et al., 2019) confirmed and added more details on the type and intensity of experiences (i.e. relationship between body movement in analogic space such as object manipulation and tactile perceptions) as essential for formation-preservation-modification of synaptic connections.

From the motor control point of view, the concept is confirmed by the schema drawn below (fig. 1) which emphasizes how relevant is the connection between the external inputs (for example, the vision and the intention to take a full glass on the table) and the consequent and consecutive generation of motor neuronal spikes to modulate the motor response (for example, reach and grab the glass).

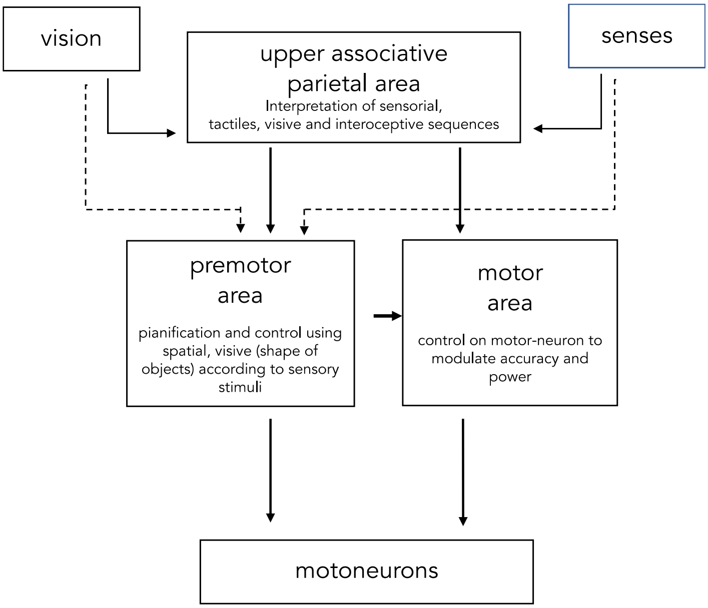

Fig. 1: Schema about the information flows within the brain to define spikes on motoneurons in response to a stimulus. Drawn adapted from Watson (2006).

For example, a subject who tries to grab a glass from a table activates a series of consecutive processes: the visive area sends information to the associative area to communicate the characteristics (exteroception) of the object (shape, size, colour) that allow integration and/or confirmation also by senses (i.e. touch; interoception) and external information (i.e. texture and weight, combination of interoception and exteroception). Then, the associative area sends all the information to activate the corresponding and right-link motoneurons balancing power and accuracy (motor control). Hence, an external stimulus (input) permits and activates a neuronal activity to mediate the motoneurons responses (output). The premotor area acts as an additional modulator of the motor area's information, integrating the present action with pre-existing information with a constant integration and update.

This additional argument highlights a basic concept about neuroplasticity: the brain is like a muscle. When you use it for certain things, it gets better at those things. The more you use it, the stronger it will become.

This implies that everything you do shapes your brain. This is the reason why the best way to get good at something is to practice it. When we use our brain, we are rewiring our brain to do something better with it for whatever purpose we are using it for. Thus, the neuronal maps evolve as learning takes place: in other words, brain evolve according to the analogic experience.

2. Neuroplasticity related to the use of digital media.

Korte (2020) investigated the effect of the use of digital media on neuronal activities, starting with the exploration of the use of fingertips on touchscreens that changes cortical activity in the motor or somatosensory cortex. It was already known that the cortical space assigned to the tactile receptors on fingertips is influenced by how often the hand is used (Elbert et al., 1995). This so-called cortical plasticity of sensory representation occurs with often repeated finger movements occur with the use of touchscreen smartphones (Gindrat et al., 2015): using electroencephalography they found that touchscreen users showed an increased cortical potential for thumbs and the index fingertips area, while no variations were found for middle finger. Furthermore, those responses were correlated with the intensity of use. In fact, the size of the cortical representation was correlated with the daily fluctuations in the use of the touchscreen for the thumb finger. These results clearly demonstrate that repetitive use of touchscreens can reshape somatosensory processing in fingertips, and they also indicate that such representations can change within a short time frame (days), related to the time-use. Furthers analysis are necessary to investigate how the expansion of cortical representation of the fingertips and thumb occurred at the expense of others motor skill but it is easy to understand that the interoception is always involved when we manage a ball or a handlebar.

Previous studies demonstrated that motor skills are inversely correlated with screen time use (Webster et al., 2019), due to a reduction in *competition* between the hippocampus (area deputy to perceive space) and motor programmes.

Considering the digital media use (multimedial board, video games, computer animation…) Gomez et al. (2019) found effects also about perception and visual objects definition. They applied FMRi over the ventral visual stream (in the ventral temporal lobe) to scan brains of adults who had played the game Pokémon (figures not visible in the real world) intensively when they were children. Only adults with past intensive Pokémon experience showed distinct cortical responsiveness to Pokémon figures in the face-recognition area. These data indicate that the use of digital media can lead to a unique functional and long-lasting representation of digital figures and objects. Moreover, all Pokémon players showed the same functional topography in the ventral visual stream for Pokémon figures, opening a new doubt: the intensive exposition to digital figures leads the brain to add new representations for novel classes of objects or object representation from digital use has negative consequences for face recognition/processing due to a *competition* within the cortical space?

In contrast, recent studies have shown that videogames positively affect the cognition process, enhancing neuroplasticity due to intense brain stimulation. Gong et al. (2019) claim that multimodal environments are associated with faster mental processing times of discrete stimulus events, potentially because they provide the user with more complete information about the environment. In fact, brain imaging observations, as consequence of cognitive stimuli, in virtual environment, have found a change in connectivity (Brilliant et al., 2019): overall, if virtual reality links cognitive and exercise stimulation (Eng et al., 2020). In point of this, is important highlight that during a video-game practice the identity of the player is multiple. As explained by Rivoltella (2012) children or adults are involved on three levels: the real player (real identity), the character in the narrative within the video-game (virtual identity) and the self-project on the character (projective identity). We believe that these multilevel thoughts are a contemporary stress for the associative nuclei and for the pre-motor cortex.

Despite the effects on brain structure and function claimed by some research, videogames, as well as virtual reality use, reveal some problems when the aim is inducing motor learning. Task transferability remains a controversial topic in the domain of virtual reality and video games. Some studies showed that there is greater transferability of tasks to the real environment only when what is performed during the learning process is closer, in terms of movement execution and space dimension, to the one performed in analogic world context (Levac et al., 2019). For example, consider learning the tennis serve, this movement clearly occurs in a three-dimensional space where the sum of movements executed by the shoulder-elbow-wrist element can result in several combinations of movements. Therefore, the learning process differ whether the gaming software considers the movement on a plane (i.e. a screen), or in a virtual reality context where the three-dimensional space around the user is considered that is always more limiting than the real space. Moreover, the learning strategies that are adopted by the subject depend on the incoming sensory information and the context (analogic world vs virtual reality) where the task is learnt: the open space in the field or a close context in the living room without interferences. Actually, virtual reality can lead to new research perspectives but is very challenging if the aim is to perfectly imitate the stimuli and the perception processes that belong to the real world (i.e. the weight of the golf club or tennis racket). The figure 2 shows a summary outline about the effects above exposed. In addition, is interesting to consider that other researchers, unfortunately, verified a negative correlation between time spent with digital media and cognitive empathy with other humans (James et al., 2017), poorer memory function, increased impulsivity, sleep disorders, increased amount of anxiety (Hoge et al., 2017) and reduced volume in the anterior cingulate cortex (area deputy to emotional reaction and memorization; Uncapher et al., 2017).

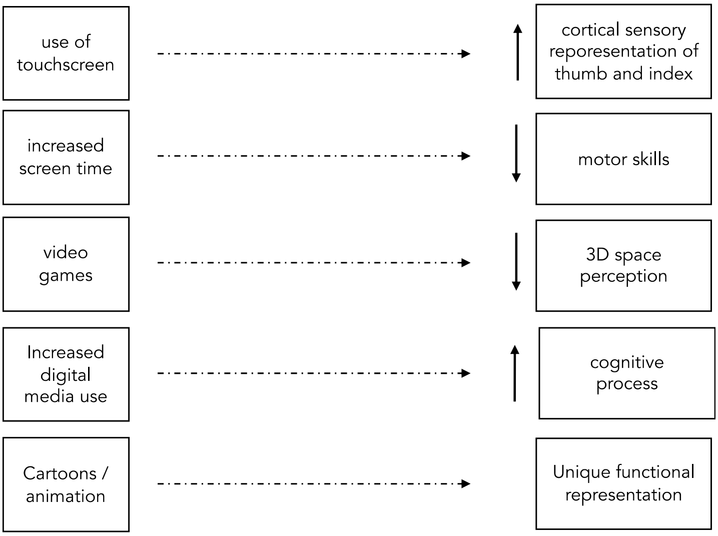

Fig. 2: Outline about the long-term effects on brain function during environment analysis

3. Different motor control due to different stimuli

We are always on digital connection. There is no doubt that digital media, most of all Internet stats, are important aspects of our modern life.

From the morning with the alarm clock hooked to satellites to the tools of domotic system, from lessons on multitask digital board to sport simulator with special glasses: now even skiing can be done in a living room. But what is happening to our ability to understand, to reason, and to memorize? The crucial point is that we are training our brain to think in the same way we use the smartphone. For example, the reading of complex stories or interconnected facts in a printed book leads to a specific recall of facts, of details, and of connection between events that is different from reading the same text on screen with pictures, music, links, and sometimes with animation (Mangen et al., 2019). The reason for the astonishing results seems to be related to how we use associations of facts exposed in specific order.

If something happens during a reading on a screen and if the brain improves different executive functions according to individual or team sport practice (Lovecchio, 2022) it is reasonable to suppose that digital practice with videogames, three-dimensional simulator, or immersive virtual reality leads to different synapse *chattering*.

Indeed, following the theory of the general motor programmes (Cano-de-la-Cuerda et al., 2015), our motor control system had to integrate a plethora of information. In Table 1 is reported a non-exhaustive list of cues that instant-by-instant our brain considers when *fire* into motoneurons during *analogic task.* In contrast, while one child performs the same action (i.e. basketball shoots) using a joystick or virtual reality glasses, the cues become less... losing connections between synapses.

This is just an example where the improvement in the virtual shot increases only the somato-representation of the thumb and the modulation of its pressure on a key and not against a ball.

3.1 Body image

Representing one's own body as distinct from other objects in the environment is the result from sensory information about the body, including visual, tactile, and proprioceptive signals (Blanke & Metzinger, 2009). The development of a representation of the body in its own hands is challenging because children must 'keep track' of a body that is constantly changing and growing while their sensory systems also change substantially (de Klerk et al., 2021). Insights into this area are important not only from a theoretical standpoint but also from a practical one because the illusory embodiment of virtual bodies has potential implication in education (Hamilton et al., 2021), entertainment, and therapy (Won et al., 2017).

Comparison between analogic and digital same task	
cues during analog task	cues during joystick task
Visual information about distance and height of the ring	Visual information from 2D screen
Interoceptive information from thigs-knees, dorso, neck, elbows, shoulders and fingertips	Interoceptive information from thumbs, index, arms and neck
Foot pressure during extension of thigs	
Weight of the ball	
Interference of light and sounds from 3D environment	

Tab. 1: List of cues receiving from a hypothetic child during the same task: throwing a ball of basket in the gym or using a joystick.

The concept of body image encompasses all aspects of an individual’s relationship with his or her own body (Barlett & Harris, 2008). In recent years, several researchers have shown that television and magazines influence how people feel and think about their bodies. In particular, the mass media emphasize a large muscular appearance that negatively affects men, while women are mostly worried about becoming thinner and thinner as proposed by the media.

Nowadays, also active video games seem to influence the body image of people, especially those who describe characters of ideal shape. Dietz (1998) found that females are portrayed as visions of beauty with large breasts and thin hips, suggesting a standard of beauty that women strive to look like. Indeed, video games offer an active role for players to control their characters allowing players to become more virtual-world-immersed: is effective the possibility to create characters in detail such as hairs and eyes colours, face shape, height, weight, and muscularity level.

Bartlett & Harris (2008) reported that players feel worse about their body after playing games due to frequent thinking about their body caused by the depictions of muscular male and thin female characters from the role assumed in the game. Conversely, after playing a video game that did not put as much emphasis on muscles, males had a decrease in the drive for muscularity.

Another work has shown that illusory body size affects perception of the environment (Tajadura-Jiménez et al., 2017). Unfortunately, negative feelings about one's own body image are related to the increase of psychological disorders such as anorexia nervosa, bulimia, and muscle dysmorphia and behavioural outcomes such as excessive exercising, dieting, and the use of steroids (James et al., 2017). For these reasons, the use of video games that emphasize body aspects might be limited or warned especially in young people to prevent the development of psychological and behavioural disorders.

Instead of this, virtual reality seems to be more appropriate and helpful in inducing controlled changes in body experience, such as a fake limb (Slater et al., 2009) as part of our own body and to produce an out-of-body experience by altering the normal association between touch and its visual correlate. On the other hand, it is also possible to use virtual reality to improve body image by examining the neural systems involved in retrieving the spatial context. Burgess and colleagues (2001) measuring the activation of the buffer for the location of scene elements between the parahippocampus (perception of space) and the precuneus (visuospatial processing, reflexions upon self) suggested that it is possible to use virtual reality to induce a controlled sensory rearrangement that facilitates an update of the locked allocentric representation of the body.

3.2 Space perception

Even if the human brain and the digital machine remain fortunately different entities, we cannot underestimate that the continuous use of computers and smartphones can change the deep structure of the brain with consequences on language, ways of relating, levels of concentration, and motor control (Andreoli, 2019). Human depth perception in general is based on different sources of information. Pictorial, oculomotor and binocular depth cues are combined to give the observer the three-dimensional impression of a scene: pictorial depth cues are two-dimensional, and the visual system interprets them in three-dimensional terms. A study by Armbrüster et al. (2008) showed that using virtual reality the virtual distances between observer and an object were perceived in correct order from the smallest to the largest displayed distance independently from the virtual condition (no space, open space, closed space) but with a slight underestimation of the real distance. Furthermore, it has been found that in virtual reality, users consistently underestimate the size of the environment, distance to objects, differences in perception of colours, contrast, space and movement, compared to real life (Paes et al., 2023). These effects are an issue of perception-action recalibration. Indeed, a study of Jones et al. (2008) confirmed that in augmented reality lower bias are obtained only if a better calibration was applied: in others words is necessary a modification of digital tools to improve the perception of space.

Even if virtual reality gives the possibility of implementing impossible or difficult actions that contribute to the acquisition of new skills, the simultaneous action/experience immersed both in virtual and in real context leads to confounded perceptual experiences (Valori et al., 2020). To understand this statement, just thinking of a person in the void while jumping a crevasse between two mountains but, instead of falling, perceive the ground under his feet (Kelly et al., 2013). In fact, the immersive virtual reality is ipso facto a situation with incongruent stimuli that determines conflict between vision and proprioception (Valori et al., 2020). This is a critical issue because children during the management of movement are mostly driven by the vision.

Again, virtual immersive reality has shown (Miehlbradt et al., 2021) some motor discrepancies when children are called to perform some easy action (i.e. visual scan of the ground during a fake flight simulating a bird). Young children (6-10 years) while wearing headsets for virtual reality seemed to use only the neck with limited torso movements compared with young adults. The authors explained that the altered visual during virtual reality strongly reweights the sensory contributions (vision as a leader) to control immature head–trunk coordination. Therefore, other researchers suggested limiting the use of virtual reality at younger ages since motor and postural control in children is not developed enough and consequently a limitation that could preserve adverse effects during sensory integration of vestibular, visual, and proprioceptive stimuli (Adams et al., 2018; Baumgartner et al., 2008).

Conclusions

Brain development is real evidence during all long life (in particular during childhood and adolescence): brain areas involved undergo intensive changes. Social media, videogames, virtual reality, 3D animation could have important effects on the brain since young people interact with others within a *fake-environment* without meeting them directly.

Technology is changing our brain. Even if, we think that removing efforts and entrusting our children to a digital tool is an advantage we can’t forget that every time we assign to a machine a human function, we are removing something from our life and our brain. Indeed, actually, when we are in a place, we look at the route on the smartphone and wait for instructions that is a *no-challenge* for the brain to mentally rebuild space and orient itself. All these new technologies are already causing a physical change in our brain: an alteration due to the absence of *challenge*. The brain is a ‘magic machine’, but it suffers from the effects of our proposal whereas the technology is ipso facto a silent proposal that changes our brain.

Families and teachers must gain a relevant role in teaching how to correct, interpret and use videogames, virtual reality and intervene early in the most critical situations. In particular, PE teachers have to help young people to increase knowledge of body, self-body image, and self-esteem through exercise and sport practice.

In our opinion, is essential the analogic experience to gain competencies and skills (i.e. to orient oneself or a map) and after introduce the digital media that accelerate the process (i.e. the use of GPS).

Remain essential and crucial remembering that the relationship between mind and body cannot be consider as close phenomenon of effect (action) and cause (mind) since the product (action) is able to retroactively on its manufacturer (mind) or, in other words; the effect on the cause (Morin, 1989). Our opinion remains fixed on analogic experience because we learn with our body in a full emotive situation (Rivoltella, 2012) within an end-less stimuli context that only the realty can supply.

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