Visual imagery without visual perception?

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The question regarding visual imagery and visual perception remain an open issue. Many studies have tried to understand if the two processes share the same mechanisms or if they are independent, using different neural substrates. Most research has been directed towards the need of activation of primary visual areas during imagery. Here we review some of the works providing evidence for both claims. It seems that studying visual imagery in blind subjects can be used as a way of answering some of those questions, namely if it is possible to have visual imagery without visual perception. We present results from the work of our group using visual activation in dreams and its relation with EEG's spectral components, showing that congenitally blind have visual contents in their dreams and are able to draw them; furthermore their Visual Activation Index is negatively correlated with EEG alpha power. This study supports the hypothesis that it is possible to have visual imagery without visual experience.

Visual Imagery and Visual Perception.

The characteristics and neural basis of visual imagery remain as a fertile field of research. In the last 25 years many authors have dedicated themselves to try to understand the mechanisms underlying the processes of evoking or generate images not directly observed and for which there are no retinian representations: "seeing with the mind's eye".

The subsiding question is whether those images are based upon contributions from primary visual areas or higher visual areas, or if visual imagery and visual perception share the same mechanisms and cortical areas.

When we see an object we can recognise it because the different features of the object are brought together via a binding mechanism. This can be made through the activation of a population of neurons or represented in a hypercolumn in the visual cortex, but being one or the other it has a specific pattern that allows that object to be recognised as unique. But we can also "see" the same object with our eyes closed, and the different features are kept. So the same pattern as before should be activated. How can this be done without retinal inputs? Is it necessary to reactivate all visual areas, namely the

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primary visual cortex, or can this be made only through the activation of higher areas?

The difficulty of studying visual imagery resides on the little objectivity of evaluating its processes. The visual imagery experience, unlike memory, language and motor control studies, is personal and difficult to access (Kosslyn & Ochsner, 1994).

On the other hand the complexity of the visual system increases with the fact that the neural information related to form, motion, and colour is not carried by one single hierarchical pathway, but by at least three (and possibly more) parallel and interacting processing pathways in the brain (DeYoe, & Van Essen, 1988). These parallel processing pathways raise another question: how is the information carried by three separate pathways brought together into a single image? The answer brings us to a central question in cognition: the binding mechanism (Treisman, 1998; 1999).

Since so many areas interact with each other, each of them dealing with different features and characteristics of the images, the question is if the re-evoking of images must activate all of them and all the hierarchic levels.

There are three main hypothesis regarding this subject: a) There is an anatomical separation between the visual cortical areas serving visual imagery and those serving visual perception; b) The areas used for visual imagery are a subset of those engaged in perception; 3) The areas subserving visual perception and imagery are the same (Roland, & Gulyás, 1994).

Shared Mechanisms.

Most of the previous studies on visual imagery were based in cognitive psychology and only the advances in neuroimaging techniques, namely PET and fMRI, have shown that mental imagery uses many of the strategies involved in perception (Kosslyn, Ganis, & Thompson, 2001).

Kosslyn defends that imagery like other cognitive functions is not an isolated and undifferentiated ability but rather a set of abilities which can be disrupted independently. When subjects mentally rotate patterns their parietal lobes (often bilaterally) and right frontal lobes are, typically, strongly activated (Cohen, Kosslyn, Breiter, DiGirolamo, Thompson, Anderson, Brookheimer, Rosen & Belliveau, 1996; Kosslyn, DiGirolamo, Thompson, & Alpert, 1998; Jordan, Heinze, Lutz, Kanowski, & Jancke, 2001; Ng, Bullmore, de Zubicaray, Cooper, Suckling, & Williams, 2001; Richter, Somorajai, Summers, Jarmasz, Menon, Gati, Georgopoulos, Tegeler, Ugurbil & Kim, 2000). When they visualise previously memorised patterns to judge if they are longer or wider the activated areas are in the occipital lobe and left association cortex (Kosslyn, Pascual-Leone, Felician, Camposano, Keenan, Thompson, Ganis, Sukel & Alpert, 1999).

Kosslyn defends that visual image construction is made step-by-step and the images are constructed through activation of individual parts, approximately imagined in the same order they are usually drawn (Kosslyn, 1988). This result is in line with the proposed two visual systems: ventral

(shape analysis) and dorsal (localisation analysis) (Ungerleider & Mishkin, 1982).

When asked to imagine a capital letter with their eyes closed subjects presented different activation patterns depending on the letter's size; if the letter was big the activated areas were the anterior portion of the medial occipital lobes, if it was smaller the posterior areas would be activated (Kosslyn, Alpert, Thompson, Maljkovic, Weise, Chabris, Hamilton, Rauch & Buonanno, 1993). These results were confirmed with PET studies showing an activation of area 17 when subjects form mental visual images (Damásio, Grabowski, Damasio, Tranel, Boles-Ponto, Watkins & Hichwa, 1993; Kosslyn, Thompson, Kim & Alpert, 1995; Kosslyn, Thompson & Alpert, 1997), indicating that mental visual imagery involves "depictive" representations and not only language-like descriptions.

In a further work, Kosslyn et al. (1999) explored the activation of area 17 with two convergent techniques: PET and repetitive transcranian magnetic stimulation (rTMS) showing the use of the primary visual cortex both in visual imagery and visual perception. In the first task subjects close their eyes during PET while visualising and comparing properties of strings. In the second task, the previous procedure performance diminished when it was preceded by rTMS at the medial occipital cortex.

Recordings from single neurons in the human medial frontal lobe while the subjects were asked to imagine previously viewed images were measured to investigate the neural substrates of visual recall (Kreiman, Koch & Fried, 2000). Single neurons were found in the hippocampus, amygdala, enthorinal cortex and parahippocampal gyrus that selectively altered their firing rates depending on the stimulus the subjects were imagining. Once again, the study revealed a common substrate for the processing of incoming visual information and visual recall.

Most of the research concerning visual imagery looks for activation in primary visual areas. These areas are topographically organised therefore preserving, in same way, retina's spatial geometry and the activation patterns in these areas evoke shape. If these areas are activated during visual imagery it would mean that imagery is based upon representations that show the information rather than describing it, i.e., visual imagery is based in true images (Kosslyn et al., 2001). This idea could imply that imagery can alter or modulate what we are really seing with strong implications on eyewitness testimony and on the veracity of visual memory. Favouring this idea are the results of Le Bihan and co-workers showing through a magnetic resonance imaging study that the same areas of the early visual cortex that are excited by visual stimulation are also activated during mental representations of the same stimulus (Le Bihan, Turner, Zeffiro, Cuénod, Jezzard, & Bonnerot, 1993).

Occipital activation during visual imagery or more precisely the activation of area 17 is not present in all the studies. It seems that for some tasks imagery is based in occipital lobe pictoric representations; however when the task does not imply the detailed geometric reconstruction of a shape, imagery does not need to evoke an activation pattern in the topographically

mapped cortical areas (Kosslyn & Ochsner, 1994). Other authors defend that visual imagery is implemented via the same neuronal mechanism underlying memory search in vision and propose an unifying model for perception and imagery (Sakai & Miyashita, 1994).

Separate Mechanisms.

Bartolomeo defends that Kosslyn's model of perceptual-imagery relationship fails to predict the observed patterns of performance in brain-damaged patients, challenging Kosslyn's arguments defending the necessity of primary visual cortex activation for visual imagery (Bartolomeo, 2002).

Farah (Farah, Peronnet, Gonon, & Girard, 1988) measured event-related electrical potentials in the brain (ERPs) during a task requiring detection of visual letters that were congruent or incongruent with letters they were instructed to imagine. Their findings indicated a "content-specific" effect of imagery on early stages of the ERP, in that imagining a letter congruent with one presented visually had a larger effect on the ERP than imagining an incongruent letter. Furthermore, the largest ERP effect was localised at electrodes recording occipital lobe activity. This pattern suggests that instructions to form images produce activity in visual centres known to process external visual information, and also that images and perceptual representations of letters may share a common neural locus. Nevertheless, although it is difficult to distinguish activity in primary visual cortex from that in visual association areas on the basis of those techniques, the ERP results suggest that primary visual cortex is probably not involved: imagery has its earliest effect on the visual ERP at the latency of the first negative component with a presumed extra-striate origin (Farah, 1989). This is consistent with the results of single-unit recordings in conscious monkeys, showing cognitive effects on neuronal activity in secondary, but not primary, visual cortex (Moran & Desimone, 1985).

The neural substrates of mental image generation were investigated with functional MRI (D'Esposito, Detre, Aguirre, Stallcup, Alsop, Tippet & Farah, 1997). Subjects listened to words under two different instructional conditions: to generate visual mental images of the words' referents, or to simply listen to each word and wait for the next word. Analyses were performed which directly compared the regional brain activity during each condition, with the goal of discovering whether mental image generation engages modality-specific visual areas, whether it engages primary visual cortex, and whether it recruits the left hemisphere to a greater extent than the right. Results revealed that visual association cortex, and not primary visual cortex, was engaged during the mental image generation condition. Left inferior temporal lobe (Brodmann's area 37) was the most reliably and robustly activated area across subjects, had activity which extended superiorly into occipital association cortex (area 19). The results of this experiment support the hypothesis that visual mental imagery is a function of visual association cortex, and that image generation is asymmetrically localized to the left.

The results by Knauff and colleagues, also with fMRI, do not support the hypothesis that primary visual cortex is involved in visual mental imagery, but rather that a network of spatial subsystems and higher visual areas appears to be involved (Knauff, Kassubek, Mulack, & Greenlee, 2000). The results support the hypothesis that visual imagery is a function of the visual association cortex.

Roland & Gulyás (1994) say that the areas used for visual imagery are parieto-occipital and temporo-occipital associative areas representing just a small sub-set of the visual areas involved in perception.

PET studies have shown activation of the superior occipital cortex, the inferior parietal cortex and the premotor cortex during the mental construction of 3D images; no activation of the primary visual areas was observed (Mellet, Tzourio, Crivello, Joliot, Denis & Mazoyer, 1996); failing to provide evidence that primary visual cortex is engaged in the generation of visual images (Cocude, Mellet, & Denis, 1999). Identifying the functional cortical fields involved in reaching for targets in extrapersonal space, and the specific fields representing visual target information in long-term memory did not show activation of the occipital lobe with the exception of the lingual gyrus close to the parieto-occipital sulcus (Kawashima, Roland & O'Sullivan, 1995).

Roland & Gulyás (1995) measured the regional cerebral blood flow (rCBF) in 11 healthy volunteers with PET (positron emission tomography). The main purpose was to map the areas of the human brain that changed rCBF during (1) the storage, (2) retrieval from long-term memory, and (3) recognition of complex visual geometrical patterns. Perception and learning of the patterns increased rCBF in V1 and 17 cortical fields located in the cuneus, the lingual, fusiform, inferior temporal, occipital, and angular gyri, the precuneus, and the posterior part of superior parietal lobules. In addition, rCBF increased in the anterior hippocampus, anterior cingulate gyrus, and in several fields in the prefrontal cortex. Recognition of the patterns increased rCBF in 18 identically located fields overlapping those activated in learning. In addition, recognition provoked differentially localized increases in the pulvinar, posterior hippocampus, and prefrontal cortex. Learning and recognition of the patterns thus activated identical visual regions, but different extravisual regions. A surprising finding was that the hippocampus was also active in recognition. Recall of the patterns from long-term memory was associated with rCBF increases in yet different fields in the prefrontal cortex, and the anterior cingulate cortex. In addition, the posterior inferior temporal lobe, the precuneus, the angular gyrus, and the posterior superior parietal lobule were activated, but not any spot within the occipital cortex. Activation of V1 or immediate visual association areas is not a prerequisite for visual imagery for the patterns. The only four fields activated in storage recall and recognition were those in the posterior inferior temporal lobe, the precuneus, the angular gyrus, and the posterior superior parietal lobule. These might be the storage sites for such visual patterns. If this is true, storage, retrieval, and recognition of complex visual patterns are mediated by higher-level visual areas. Thus, visual learning and recognition of the same patterns make use of identical visual areas, whereas retrieval of this material from the storage sites

activates only a subset of the visual areas. The extravisual networks mediating storage, retrieval, and recognition differ, indicating that the ways by which the brain accesses the storage sites are different. These results indicate that the early visual areas are not engaged in visual imagery of scenes, single patterns or multiple geometrical patterns to any significant extent (Roland & Gulyás, 1994). Mellet recorded regional cerebral blood flow (rCBF) while subjects performed a task that required high-resolution visual mental imagery, in order to address the controversy regarding activation of the primary visual area during visual mental imagery (Mellet, Tzourio-Mazoyer, Bricogne, Mazoyer, Kosslyn, & Denis, 2000). The results revealed no activation in primary visual area for imagery based on verbal description, providing strong evidence that imagery based on verbal descriptions can recruit regions known to be engaged in high-order visual processing.

Clinical Evidence.

There are several clinical evidences indicating that different areas are involved in both processes. Patients with localised lesions loose the ability of imagining images while preserving visual perception and vice-versa (Basso, Bisiach & Luzzatti, 1980; Behrmann, Winocur & Moscovitch, 1992). In the latter it was concluded that rich internal representations can be activated to support visual imagery even when they cannot support visually mediated perceptions of objects.

In a patient with bilateral lesions of the temporo-occipital cortex, with agnosia, alexia, achromatopsia and prosopagnosia, mental imagery was perfectly preserved for the same entities: object recognition, reading, colour and face processing (Bartolomeo, Bachoud-Lévi, de Gelder, Denes, dalla Barba, Brugières & Degos, 1998). The authors defend that the results support the existence of different mechanisms for visual perception and visual imagery. In a different study visual imagery was preserved in a patient with total cortical blindness after bilateral posterior cerebral artery infarctions (Goldenberg, Müllbacher & Nowak, 1995). The patient denied her blindness mistaking mental images for visual perceptions. It seems that severe damage to primary visual cortex is compatible with visual imagery, however the possibility of existence of small islands of visual cortex, allowing the generation of visual images, should be considered.

Alpha Activity and Visual Imagery.

Furthermore it is known that there are correlations between EEG and visual activity. The alpha rhythm is mainly generated in the visual cortex occuring in the frequency range of 8-13 Hz. Some authors regard alpha activity attenuation (i.e. decreasing of the power) or blocking as an indicator of visual imagery in general (Barrett & Ehrlichman, 1982; Cantero, Atienza, Salas & Gómez, 1999; Goodman, Beatty & Mulholland, 1980; Schupp, Lutzenberger, Birbaumer, Miltner & Braun, 1994; Williamson & Kaufman, 1989; Williamson, Kaufman, Lu, Wang & Karron, 1997). Alpha power attenuation with visual content was also confirmed in sighted subjects during

visual exploration by Goldie (Goldie & Green, 1960). Alpha power was lower in the right hemisphere when subjects performed an imaginative block rotation task, and was suppressed when subjects either watched or played Pong (TV tennis) (Rebert, & Low, 1978); watching Pong was as effective as playing the game in producing alpha asymmetry in the parietal region, but motor involvement enhanced asymmetry at central and temporal leads. EEG frequency bands are correlated with visual imagery and abstract thought; and the alpha power is more affected by visual mentation then by abstract mentation (Lehman, Henggler, Koukkou & Michel, 1993; Lehman & Koenig, 1997). Parieto-occipital alpha activity was suppressed strongly while subjects visualized and evaluated letters, but forming a visual image caused less suppression than did direct inspection of the imaged pattern (Salenius, Kajola, Thompson, Kosslyn & Hari, 1995). Magnetoencephalographic studies have also shown a dampening of the alpha activity within 200 ms after the appearance of a visual stimulus and also during visual imagery (Hari, Salmelin, Mäkelä, Salenius & Helle, 1997).

Studies with blind subjects.

Studies in blind subjects have also been used to research visual imagery in the absence of vision. Imagery tasks in patients with cortical blindness provide strong evidence that primary visual cortices are not essential for the mediation of visual images recalled from memory (Chatterjee & Southwood, 1995).

Aleman and colleagues explored the capacity of congenitally blind subjects in performing tasks that are mediated by mental visual imagery in sighted subjects (Aleman, van Lee, Mantione, Verkoijnen, & de Haan, 2001). Subjects performed two tasks: a pictoric task where they mentally compared the contour shape of objects and another, spatial, where they had to imagine an imaginary path through 2D and 3D matrices. Although blind subjects performed worse than sighted they were able to perform both tasks.

Another study with PET showed that subjects who became blind very early in life show activation foci in occipito-temporal and visual association cortical areas while performing a task of visual imagery (imagery of object shape) that is triggered auditorily (De Volder, Toyama, Kimura, Kiyosawa, Nakano, Vanlierde, Wanet-Defalque, Mishina, Oda, Ishiwata & Senda, 2001).

Uhl and colleagues studied the cortical activity patterns measured in the scalp in blind and sighted subjects. They detected event-related slow negative DC potential shifts when subjects imagined textures they had previously touched (Uhl, Kretschmer, Lindinger, Goldenberg, Lang, Oder & Deecke, 1994). All the subjects claimed to have simultaneous visual imagery and occipital negative shifts were observed. Although they had never had visual perception, blind subjects presented the same variations as sighted but with a lower amplitude.

Three experiments compared congenitally blind and sighted adults and children on tasks presumed to involve visual imagery in memory (Zimler & Keenan, 1983). The first two experiments examined Pavio's modality-specific

imagery hypothesis. Experiment 1 used a paired-associate task with words whose referents were high in either visual or auditory imagery. The blind, like the sighted, recalled more high-visual-imagery pairs than any others. Experiment 2 used a free-recall task for words grouped according to modality-specific attributes, such as color and sound. The blind performed as well as the sighted on words grouped by color. In fact, the only consistent deficit in both experiments occurred for the sighted in recall of words whose referents are primarily auditory. These results challenge Paivio's theory and suggest either (a) that the visual imagery used by the sighted is no more facilitating than the abstract semantic representations used by the blind or (b) that the sighted are not using visual imagery. Experiment 3 used Neisser and Kerr's imaging task. Subjects formed images of scenes in which target objects were described as either visible in the picture plane or concealed by another object and thus not visible. On an incidental recall test for the target objects, the blind, like the sighted, recalled more pictorial than concealed targets. This finding suggests that the haptic images of the blind maintain occlusion just as the visual images of the sighted do. In several studies involving visual imagery, the congenitally blind showed only slight differences in performance when compared with sighted subjects (Arditi, Holtzman, & Kosslyn, 1988; Bailes, & Lambert, 1986; De Beni & Cornoldi, 1988; Marmor & Zaback, 1976; Zimler & Keenan, 1983); the blind may employ other strategies to solve the experimentally posed problems.

Spatial knowledge and metric properties seem to be preserved in congenitally blind subjects (Haber, Haber, Levin & Hollyfield, 1993). In pictorial and spatial representations of two- and three-dimensional matrices of differing complexity, the congenitally blind only perform worse than sighted subjects in the latter (Cornoldi, Calore, & Pra-Baldi, 1979; Cornoldi, Cortesi & Preti, 1991). A psychological study conducted on subjects born blind indicates that they have capabilities to generate visuo-spatial images (Vecchi, 1998).

Kaski defends that the studies in congenitally and cortically blind oppose the hypothesis that visual perception is a requisite for visual imagery (Kaski, 2002).

Blind subjects' dreams.

Dreams with visual content are expressions of visual imagery. Therefore if dreams with visual content could be demonstrated in congenitally blind persons, this would imply that visual imagery is possible in subjects who have been prevented from having visual experiences. Furthermore, this would allow one to infer that visual imagery does not depend on specific visual perception, but can emerge from activation of visual cortex by non-visual inputs (Lopes da Silva, 2003).

It is open to discussion whether congenitally blind subjects have dreams with visual imagery content, and if they do, whether this ability represents images capable of being represented graphically.

Since for sighted subjects the dreaming experience is associated with

visual activity, it used to be widely thought that blind persons do not dream. This was strongly refuted by several authors and it is nowadays accepted that the dreams of the blind are vivid and self-engaging (Deutsch, 1928; Jastrow, 1900; Kerr, 2000). Furthermore, it is currently accepted that the congenitally blind, or those who lose their sight before the age of 5 or 7, have dreams without visual content (Kerr, 2000). Jastrow's studies on children's dreams found visual imagery only in those whose blindness occurred after 5-7 years of age (Jastrow, 1900), a period associated with the inclusion of visual activity in dreams, which coincides with the beginning of autonomous dreaming (Foulkes, 1982). Some authors also report that subjects who are born blind report dreams which do not include any description of scenes or landscapes but contain mostly sounds, touch sensations or emotional experiences (Holzinger, 2000; Hurovitz, Dunn, Domhoff & Fiss, 1999; Lavie, 1996). Laboratory dream data obtained for 10 blind subjects showed that blind and normal dreams were identical, except for 2 congenitally blind subjects whose dreams did not have visual components (Kerr, Foulkes & Schmidt, 1982).

This knowledge may, however, be questioned. Using objective measurements, to access visual imagery in blind subjects, we evaluate visual content in dreams and its relation with EEG's spectral rhythms (Bértolo, Paiva, Pessoa, Mestre, Marques & Santos, 2003).

Our results

Taking the above information into consideration, we analysed EEG alpha power in congenitally blind subjects, as a possible indicator of the visual content of their dreams (Bértolo et al., 2003), and evaluated the ability of congenitally blind to graphically represent the dream-evoked images. We tested 10 congenitally blind and 9 sighted subjects, during two consecutive nights of home PSG (polysomnographic) recordings, with serial awakenings for dream recall.

Content analysis was performed on the dream reports using the Hall & Van de Castle definitions to code the different activities (Domhoff, 1996). The dream reports of the blind subjects were vivid with tactile, auditory and kinaesthetic references, but also with visual content. Neither the Global Activity Index (GAI) nor the Visual Activity Index (VAI) showed any difference between the two groups (Bértolo et al., 2003). When comparing the Content variables with the EEG spectral components, we observed in both groups (blind and sighted) a negative correlation between the VAI and the alpha power: where the visual activation index increased, the alpha power decreased (Bértolo et al., 2003). This negative correlation between alpha and the VAI was also found in a previous study with a smaller sample (Bértolo & Paiva, 1999).

Two different tasks were used to evaluate graphical representations; in both of them sighted subjects performed the tasks with their eyes closed. First the subjects were asked to make a drawing of one their dream scenes. A qualitative analysis of these representations was performed with respect to complexity and content. In the second task the subjects were asked to draw " a

human figure the best you can". Two different scales were used to evaluate this task. Quoc Vu's Test (Cambier & Quoc Vu, 1985) and The Goodenough scale (Goodenough, 1928).

All the subjects performed the first task of graphical representation, the drawing of a dream scene (Fig.1). Blind subjects were able to represent graphically the oneiric scenes they previously described orally. No statistical differences were found between the groups (Bértolo et al., 2003).

Fig.1. Graphical representation of an oneiric scene by a blind subject. (Bértolo et al., 2003).

            a)   **b)**

Fig. 2. Goodenough's Human Figure. a) Drawings of blind subjects; b) representations by sighted subjects. (Bértolo et al., 2003).

With respect to the "Drawing of the Human Figure" (Fig.2) the only statistical difference between the groups for Quoc Vu's Test was related to the vertical occupation of the drawing: the blind tended to draw on the left side of the sheet of paper. On Goodenough's scale, the human figure was recognisable in both groups, and of the 51 items characterising the drawing only one was statistically different: ears are more often represented by blind than by sighted subjects (Bértolo et al., 2003).

In conclusion, the congenitally blind are not only able to describe what may be the visual content of their dreams verbally, but they can provide, through drawing, a graphical representation of such content, and a significant negative correlation between the Visual Content of the dreams and the alpha power was found in both groups.

DISCUSSION

According to these results, the congenitally blind, who have never experienced sight, are able to visualise. This is in line with previously mentioned studies related to the capacity for visual imagery in individuals who are born blind, showing that they present only slight or no differences when compared with normal sighted subjects (Arditi et al., 1988; Bailes & Lambert, 1986; Cornoldi et al., 1979, 1991; De Beni & Cornoldi, 1988; Haber et al., 1993; Marmor & Zaback, 1976; Vecchi, 1998; Zimler & Keenan, 1983).

The observation of alpha attenuation/visual content correlation along with the no differences in the graphical representations leads us to hypothesize that blind subjects can produce virtual images, that is, that their dreams correspond to the activation of visual cortical regions.

It has in fact been established by several authors that congenitally blind subjects use the visual cortex to process different kinds of information, namely auditory (Kujala, Alho, Huotilainen, Ihmoniemi, Leinonen, Rinne, Salonen, Sinkkonen, Standertskjöld-Nordenstam & Näätänen, 1997; Kujala, Alho, Kekoni, Hämäläinen, Reinukainen, Salonen, Standertskjöld-Nordenstam & Näätänen, 1995), tactile (Sadato, Pascual-Leone, Grafman, Ibañez, Deibar, Dold & Hallett, 1996), somatosensitive (Röder, Rösler, Hennighausen & Näcker, 1996), and during the encoding and transformation of haptic images (Röder, Rösler & Hennighausen, 1997). Lopes da Silva defends that one possible conclusion from our study (Bértolo et al., 2003) is that auditory and tactile inputs can create virtual images in the brains of congenitally blind subjects which can be revealed in their dreams (Lopes da Silva, 2003).

Behind such controversy lies the fact that experience is considered essential both for visual imagery and for visualisation. Visualisation without previous experience, as is the case for congenitally blind, would indicate the existence of visual imagery independent of visual perception. This implies that the born-blind subjects are capable of using other sensory modalities to integrate these inputs via the visual system to produce concepts capable of graphical representation.

The discussion around the term "visual imagery" - seeing with the "mind's eye" - is far from being resolved. Nevertheless the use of the term in our paper was carefully applied. We totally agree that sometimes blind subjects use terms as "seeing" in their daily lives metaphorically. But this does not imply that they are unable to produce mental visual images. In informal talks blind subjects told us that when they sign their names they don't use a memorised set of movements, instead they "visualise" their signature and reproduce it. One of the volunteers told us that during dream he experienced visual images but whenever he report that to anyone he was told he didn't see things he just felt them; and so he was very reluctant to share those experiences with others.

When some researchers defend that those are not visual images but are instead mental representations that preserve spatial and metric properties the study by Aleman et al. (2001) should be taken into consideration. In this study the authors tried to separate pictorial from spatial representations and they concluded that although blind made significantly more errors than sighted they were able to perform both the spatial as the pictorial imagery tasks.

It is true that alpha activity is not solely modulated by visual activity but although we classified other dream activities the strongest correlation was found for visual imagery.

Regarding the drawings it is difficult to justify such a variety of scenes, objects and characters depicted based only in the preservation of metric and spatial properties with no pictorial representations.

In this sense, we defend that visual imagery is possible without visual perception or experience, and we consider that studies with blind subjects are an important tool to access the underlying mechanisms of visual imagery.

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