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Research report

Visual dream content, graphical representation and EEG alpha activity in congenitally blind subjects

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Abstract

It is currently claimed that congenitally blind do not have visual imagery and are therefore unable to present visual contents in their dreams. The aim of our study was to quantitatively evaluate the existence of visual imagery in born-blind dreams and to correlate it with objective measures, such as sleep EEG frequency components, namely with alpha attenuation (regarded as an indicator of visual activity), and graphical analysis of dream pictorial representations. The investigation was carried out via simultaneous recordings of dream reports and polysomnography, during nocturnal sleep at volunteers' homes; scheduled regular awakenings during the night provided the data for dream and EEG analysis. In the morning, subjects were asked to make a drawing of their dream images. Congenitally blind ($n=10$) were comparable to normal sighted subjects ($n=9$): the two groups presented equivalent visual activity indices, and no differences in the analysis of graphical representation of dreaming imagery. However, blind subjects presented a lower rate of dream recall than sighted (27% versus 42%). Both groups had significant negative correlation between Visual Activity Index (VAI) and alpha power in the central and occipital O2 derivations (blind: C4: $r=-0.615$, $P<0.005$; O2: $r=-0.608$, $P<0.006$; sighted: C4: $r=-0.633$, $P<0.01$; O2: $r=-0.506$, $P<0.05$). This correlation was weaker for the blind in O1 ($r=-0.573$, $P<0.05$) and non-existent for the sighted. Blind individuals have significantly lower alpha activity in the central derivation. In conclusion, the congenitally blind have visual content in their dreams and are able to draw it and, as expected, their VAI is negatively correlated with EEG alpha power.

Theme: Neural basis of behaviour

Topic: Biological rhythms and sleep

Keywords: Dreams; Visual imagery; Congenitally blind; Alpha activity

1. Introduction

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 [16,38,40]. 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 [40]. 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 [34,37,44]. Laboratory dream data obtained for 10 blind subjects showed that blind and normal dreams were identical, except for two congenitally blind subjects whose dreams did not have visual components [41].

This knowledge may, however, be questioned. In several studies involving visual imagery, the congenitally blind showed only slight differences in performance when compared with sighted subjects [2,4,14,47,64]; the blind may employ other strategies to solve the problems posed experimentally. Spatial knowledge and metric properties seem to be preserved in congenitally blind subjects [29]. In pictorial and spatial representations of two- and three-dimensional matrices of differing complexity, the congeni-

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tally blind only perform worse than sighted subjects in the latter [12,13]. A psychological study conducted on subjects born blind indicates that they have capabilities to generate visuo-spatial images [61].

Dream content analysis is open to many criticisms, due mainly to subjectiveness. Nevertheless, Hall and Van de Castle have proposed a highly reproducible index that is widely used in dream content analysis [30]. None of the studies mentioned previously used this classification system. A fundamental difficulty of assessing whether dreams with visual content occur in the congenitally blind is the lack of accepted objective physiological measures.

One possibility is to use recordings of Rapid Eye Movement episodes (REMs) that are related to visual exploration [32,36]. Some authors did not record REMs in blind subjects; this led them to conclude that the blind do not have visual content in their dreams [7]. Recent studies which describe rapid eye movements during blind persons' dreams have refuted this, however [39].

Furthermore it is known that there are correlations between EEG and visual activity. Some authors regard alpha activity attenuation or blocking as an indicator of visual imagery in general [6,11,28,57,62,63]. 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) [50]; 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 than by abstract mentation [45,46]. 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 [56]. 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 [31].

Taking this information into consideration, we analysed EEG alpha power in congenitally blind subjects, as a possible indicator of the visual content of their dreams. We also checked for differences regarding the correlations between occipital derivations (O1 and O2) and central derivations (C4). Finally, we tested the ability of congenitally blind to graphically represent the dream-evoked images.

2. Material and methods

The Ethical Committee of the Faculty of Medicine of Lisbon accepted the study.

We tested 10 congenitally blind and nine sighted subjects, during two consecutive nights of PSG (polysomnographic) recordings, with serial awakenings for dream recall.

2.1. Subjects

The blind volunteers were selected with the support of ACAPO, the Portuguese association for the blind.

Ten congenitally blind individuals (age: 28.2±5.2; five males and five females) and nine sighted subjects (age: 28.2±5.5; four males and five females) were evaluated (Table 1). There were no differences between the two groups regarding laterality (left-handed/right-handed). The

Table 1
Summary of subjects' data

Subject	Blind/sighted	Age	Gender	Education	Right-handed	Epochs obtained	Epochs with recall
1	B	35	M	Psychologist	Yes	4	3
2	B	28	M	Psychologist	Yes	8	3
3	B	30	F	Journalist	Yes	7	2
4	B	26	M	High school	Yes	7	2
5	B	25	F	Psychologist	Yes	6	2
6	B	19	F	Psychologist	Yes	5	2
7	B	24	M	High school	Yes	8	0
8	B	27	F	High school	Yes	8	0
9	B	36	F	High school	Yes	6	2
10	B	32	M	Computer engineer	Yes	7	2
11	S	25	F	Historian	Yes	6	1
12	S	35	M	Professor	Yes	7	6
13	S	26	M	Architect	Yes	5	2
14	S	36	F	High school	Yes	6	3
15	S	24	M	High school	Yes	7	2
16	S	27	F	Journalist	Yes	7	2
17	S	19	F	Medical student	Yes	8	3
18	S	32	M	High school	Yes	6	2
19	S	30	F	Lawyer	Yes	8	4

selection criteria were: young adults (between 18 and 40 years old); education level standardization (minimum a high school diploma), and a good oral capacity; healthy subjects, with no active medical diseases, no psychiatric diseases, no sleep disorders and with regular sleep schedules; taking no medication other than oral contraceptives.

Three preliminary questionnaires were completed to confirm inclusion and exclusion criteria: (a) General questionnaire on issues related to health and habits and blindness diagnosis; (b) Psychological test (SCL 90) [15] to trace their symptomatic profile, excluding those subjects with a perturbation level above 2 for each of the items considered (somaticism, obsession, compulsion, sensitivity, depression, anxiety, hostility, phobic anxiety, paranoia, psychoticism); (c) Sleep log diary for 2 weeks with a key role for the PSG recording starting time.

2.2. Recordings

2.2.1. Polysomnographic (PSG) recordings

The recordings were taken at the volunteer's home during two consecutive nights by a specialised technician with the ambulatory polysomnographic recorder Embla™ (manufacturer Flaga hf Medical Devices, Vesturhlíd 7, 105 Reykjavik, Iceland) with 16 PSG channels: eight EEG channels (F4, F8, C4, T4, P4, T6, O1 and O2 with reference to A1 (system 10–20)); two EOG channels (vertical and horizontal); one EMG channel (mentonian); one ECG channel; one air-flow channel; one snoring channel; one oximetry and pulse channel. Somnologica 2.0 software (the same manufacturer as Embla) was used for the visual sleep scoring, based on the Rechtschaffen and Kales rules [51], for the corresponding hypnograms and for the automatic signal analysis.

2.2.2. Dream reports

Standard instructions were given during the electrode placement. Awakening with a digital, programmable alarm clock, timed by the previously recorded sleep–wake schedule (with no interaction, dialogue or sound), was carried out four times each night, every 90 min. The time for the first awakening was determined from the diary, typically 90 min after the mean 'going-to-bed time'. After being awakened, the volunteer would record everything he/she was thinking prior to being woken, on a voice-activated tape recorder. Once the subject was sure that there was nothing else to relate he/she could go back to sleep.

2.3. Data analysis

Content analysis was performed on the dream reports and spectral analysis on the sleep EEG.

2.3.1. Content analysis

We used two of the 10 Hall and Van de Castle categories: Activities and Emotions. One of our main goals was to study visual activity, and this is fully covered by the activity category. The eight classes of activities are coded as follows: Physical (P), Movement (M), Change in Location (L), Verbal (V), Expressive Communication (E), Visual (S), Auditive (A), Thought (T). The classes of emotions are coded as Fury (FU), Apprehension (AP), Happiness (HA), Sadness (SA), Confusion (CO). We used the Hall and Van de Castle definitions to code the different activities [17].

2.3.2. Computing parameters

The words for each class are added together and then divided by the total number of words (TW) of the recording to give a 0 to 100 scale. Each recording was analysed independently by two experimenters, who were unaware of the volunteer category. For each analysis, the parameters below were calculated. The final individual dream value was the mean of the two independent scores.

Global Oneiric Activity Index: GAI

$$= \frac{\sum_p P + \sum_m M + \sum_l L + \sum_v V + \sum_e E + \sum_s S + \sum_a A + \sum_t T}{\mathrm{TW}} \times 100$$

$$\text{Visual Activity Index: VAI} = \frac{\sum_s S}{\mathrm{TW}} \times 100$$

The lower case letters (p, m, l, v, etc.) represent the indices of the respective variables (P, M, L, V, etc.).

2.3.3. Spectral analysis

Spectral analysis was performed for the C4–A1, O2–A1 and O1–A1 EEG channels, for every awakening, with recall. For every period, the initial moment was the awakening signal, and the analysis was made backwards, for the preceding 5-min period. For every 5-min period, the mean for each spectral band was calculated for successive 30-s epochs of that period. In each epoch, the signal was analysed with 256 points sample FFT (Fast Fourier Transform) with a 50% overlap. The spectra were divided into the frequency bands corresponding to the main EEG rhythms: delta (0.5–3.9 Hz), theta (4–7.9 Hz), alpha (8–11.9 Hz), sigma (12–13.9 Hz), beta (14–24.9 Hz) and higher frequencies (25–50 Hz).

2.4. Graphical representations

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

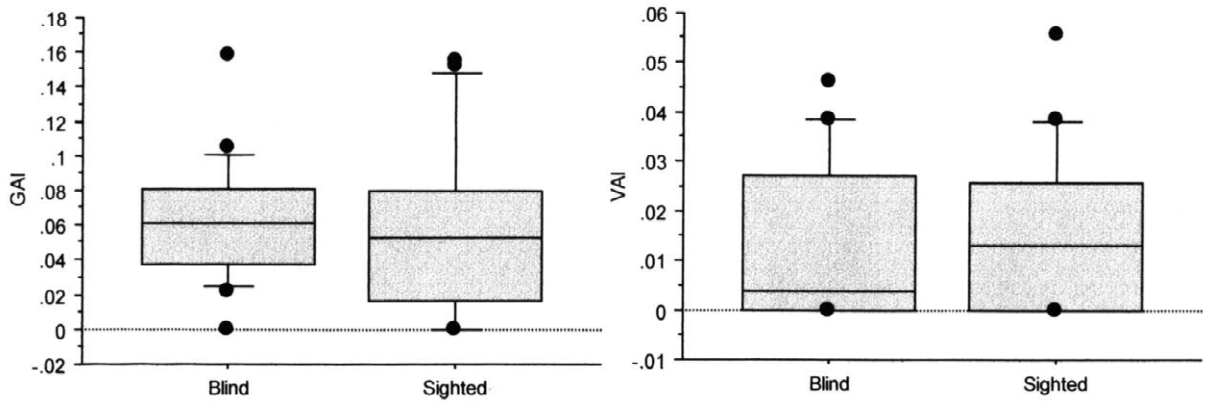

Fig. 1. Box plots for the Global Activation Index (GAI) and the Visual Activation Index (VAI) comparing blind and sighted subjects, showing no significant differences between the groups.

with respect to complexity and content. Three different judges analysed all the drawings, without knowing if the author was blind or sighted, and a mean was calculated for each subject. Complexity was scored using an ad hoc 1 to 5 scale (1 for scribble and 5 to fully detailed). For content, three main classes were considered: landscapes; objects, and human figures. The drawings were classified according to the presence or absence of those classes. 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. (i) Quoc Vu's Test [10] analyses three items: Trace analysis; Spatial organization index, and Type of drawn characters through the following classes: Amplitude (small, normal, large), Character (rectilinear, curvilinear, mixed), Stereotypes (yes, no), Horizontal Occupation (inferior, centre, superior), Vertical Occupation (left, centre, right), Organized (bottom/top, top/bottom), Out of Order (yes, no) and Type of characters (scribble, primitive, full body). (ii) The Goodenough scale [27] has two categories: A if the human figure is not recognizable and B if it is recognizable. The latter involves 51 dichotomic items regarding the amount of details drawn, their proportionality, bidimensionality, opacity, congruency, plasticity, visuo-motor co-ordination and profile. Two independent judges scored both scales for all the drawings and the means were calculated.

3. Results

3.1. Dream content evaluation

The alarm clock rang four times each night for every subject in a total of 152 awakenings. Not all the awakenings were successful and the total of epochs obtained was 126, of which 43 provided recall (approx. 34%). The blind group showed only 27% of recall against 42% of the sighted group; the difference between the recalls is significant ($P<0.05$). Two of the 10 blind subjects had no recall in the two nights (see Table 1, subjects 7 and 8).

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) ($\mathrm{mean}_{\mathrm{blind}}=0.064$; $\mathrm{mean}_{\mathrm{sighted}}=0.058$) nor the Visual Activity Index (VAI) ($\mathrm{mean}_{\mathrm{blind}}=0.013$; $\mathrm{mean}_{\mathrm{sighted}}=0.016$) showed any difference between the two groups for the Mann–Whitney U-test (Fig. 1). However the alpha power presented differences between the two groups, for the C4 derivation, with lower activity in the blind group (alpha-C4: $U=73.0$, $P<0.01$; alpha-O1: $U=94.5$, n.s., alpha-O2: $U=100.0$, n.s.) and higher variability in O2 for the blind ($F=5.466$, $P<0.01$) (Fig. 2).

Our null hypothesis is that there is no correlation between the Visual Activation Index and the alpha power.

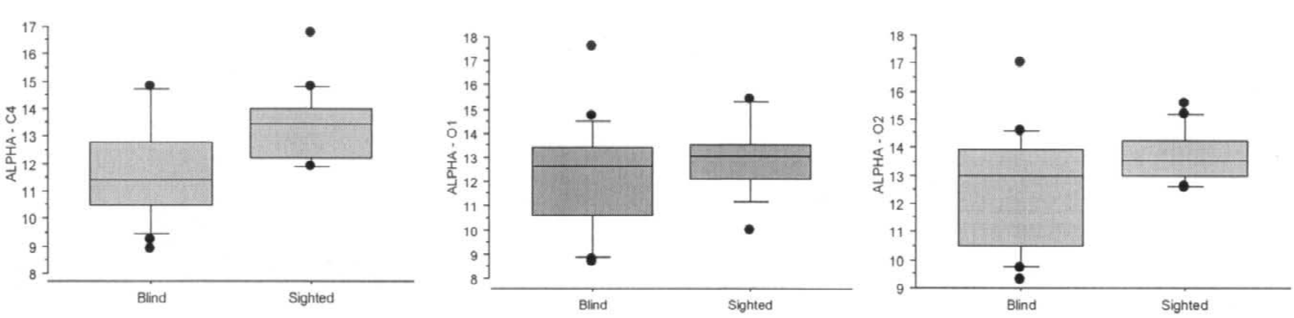

Fig. 2. Box plots for the Alpha power in C4, O1 and O2 derivations comparing blind and sighted subjects, showing differences between the groups.

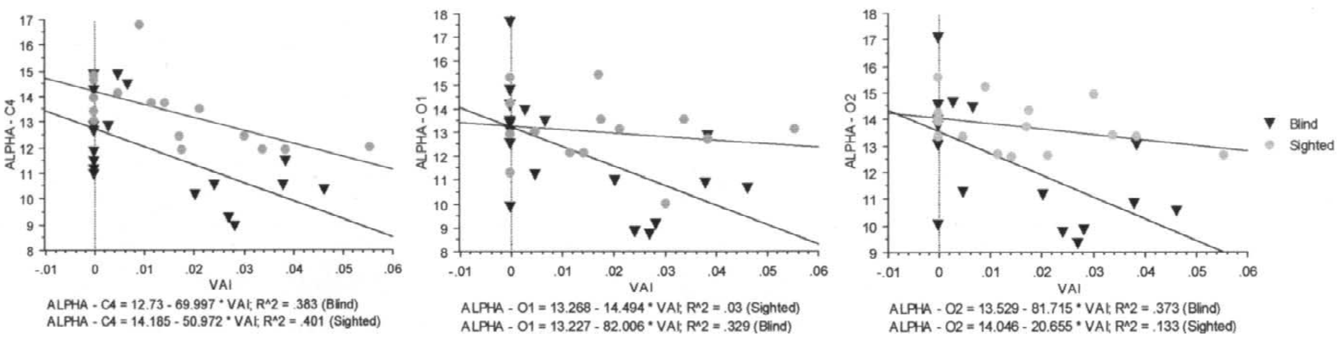

Fig. 3. Scatterplot and regression line for correlation between VAI and alpha-C4, alpha-O1 and alpha-O2 for blind (▼) and sighted (●) subjects. For the blind we have: alpha-C4 versus VAI (slope $= -69.997$; $t = -3.121$, $P < 0.01$); alpha-O1 versus VAI (slope $= -82.006$, $t = -2.799$, $P < 0.05$); alpha-O2 versus VAI (slope $= -81.715$; $t = -3.065$, $P < 0.01$). For the sighted: alpha-C4 versus VAI (slope $= -50.972$, $t = -3.061$, $P < 0.01$); alpha-O1 versus VAI (slope $= -14.494$, $t = -0.607$, n.s.); and alpha-O2 versus VAI (slope $= -20.655$, $t = -2.194$, $P < 0.05$).

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 (Fig. 3). This was true for the two groups, for both derivations, C4 and O2 (blind: C4: $r = -0.615$, $P < 0.005$; O2: $r = -0.608$, $P < 0.006$; sighted: C4: $r = -0.633$, $P < 0.01$; O2: $r = -0.506$, $P < 0.05$). For O1 the correlation was only found for the blind group, although it was weaker (blind O1: $r = -0.573$, $P < 0.05$; sighted O1: $r = -1.72$, n.s.).

All the subjects carried out the first task of graphical representation, the drawing of a dream scene (Fig. 4). Blind subjects were able to represent graphically the oneiric scenes they previously described orally. The calculated mean for complexity was two for both groups, showing no statistical differences. Regarding content, landscapes were present in 70% of the drawings, objects in 90% and human figures in 10%. No statistical differences were found between the groups.

With respect to the 'Drawing of the Human Figure' (Fig. 5) 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

Fig. 4. Graphical representation of an oneiric scene by a blind subject.

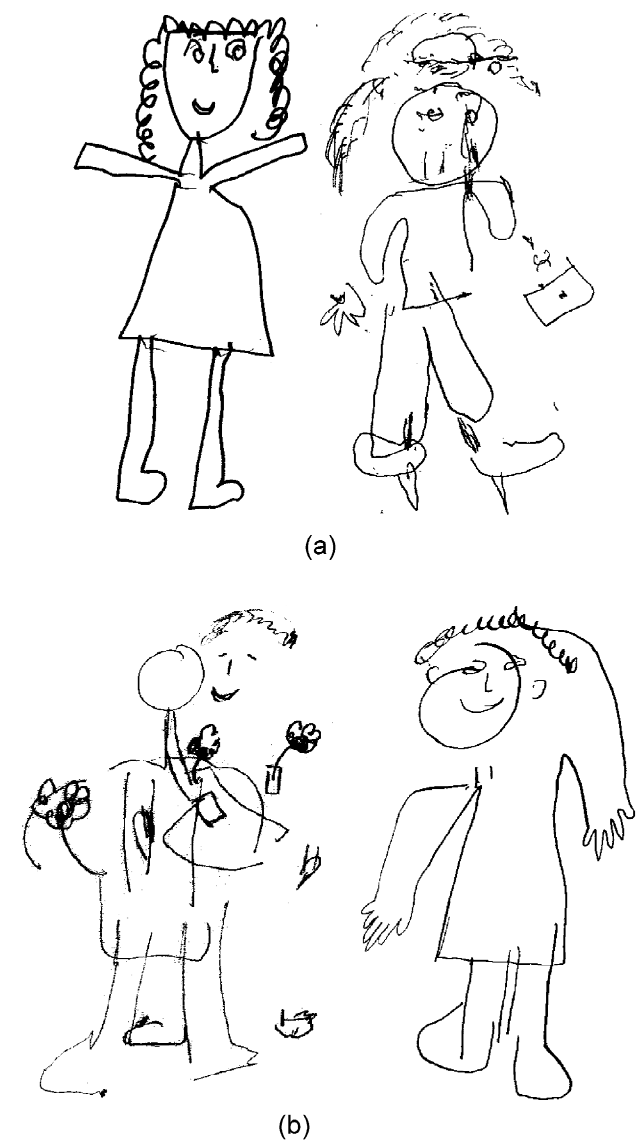

Fig. 5. Goodenough's Human Figure. (a) Drawings of blind subjects; (b) representations by sighted subjects.

the sheet of paper ($\chi^2 = 7.468$; gl = 2; $P < 0.01$). On Goodenough's scale, the human figure was recognisable in both groups (category B), and of the 51 items characterising the drawing only one was statistically different: ears are more often represented by blind than by sighted subjects ($\chi^2 = 6.739$; gl = 1; $P < 0.05$).

4. Discussion

The methodology should be considered and discussed in the context of the intended goal: a polysomnographic study of visual dreaming in blind subjects. This implies the recording of left and right occipital derivations, together with standard scoring derivations (C4); however due to the complexity of the experimental set-up, a larger number of channels has been recorded for future topographic analysis. The option to carry out the EEG recording in the right hemisphere was based on the fact that all our subjects were right-handed, and on previous studies which argue that there is an asymmetry in dreaming and visual imagery [5,9,23,49,60]. Studies on callostomized patients showed they have superior spatial information-processing ability in the right hemi-cortex [24,59]. Some reports on greater cortical activation in the right hemisphere during REM sleep have supported the hypothesis that dreaming is a right hemisphere function [26,33,54]. Other studies have drawn different conclusions, however, and seem to invalidate that hypothesis [1,3,19,22,58]. A recent work using Positron Emission Tomography suggested that right hemispheric specialisation in REM saccadic eye movement control was related to visual imagery and reciprocal inhibition in the contralateral homologous area during higher cortical functioning [35]. This remains an open issue, but we are inclined to agree with those defending the right hemisphere dominance for visual imagery, since, in the present study, correlation with visual imagery was less significant for the left occipital derivation.

Our finding of visual content in the dreams of persons who are born blind differs strongly from previous published studies.

The main results of this work are: (a) 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. The differences between the sighted and blind are only slight; (b) a significant negative correlation between the Visual Content of the dreams and the alpha power was found in both groups. Alpha power attenuation with visual content was also confirmed in sighted subjects during visual exploration by Goldie [25] and during visual imagery [6,11,28,45,46,50,56,57,62,63]. This negative correlation between alpha and the VAI was also found in a previous study with a smaller sample [8].

According to these results, the congenitally blind, who have never experienced sight, are able to visualise. Jastrow's studies on children's dreams found visual imagery only in those whose blindness occurred after 5–7 years of age [38], a period associated with the inclusion of visual activity in dreams, which coincides with the beginning of autonomous dreaming [21]. Opposing these data and favouring our results are other 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 [2,4,12–14,20,29,47,61,64].

The observation of alpha attenuation/visual content correlation along with 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 [42,43], tactile [55], somatosensitive [53], and during the encoding and transformation of haptic images [52].

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.

Some methodological issues should also be mentioned. Our sample of born-blind subjects is larger ($n = 10$) when compared with others ($n = 2$) [41]; in our sample, although dream recall was absent in two of the subjects, it was very clear in eight of them, showing the relevance of sample size. Dreams were recorded in the volunteers' homes, using standard multi-channel polysomnography, and awakenings for dream recording were sequentially programmed. Other published studies either carried out recordings in the laboratory or used the last recalled morning dreams [18,41]. The other significant difference was the unbiased use of the Hall and Van de Castle coding criteria in our experimental set-up. To quote Domhoff, "the set of nominal categories developed by Hall and Van de Castle is the most comprehensive and widely used empirical system of content analysis", and this allowed important cross cultural studies. In addition, the use of blind classification of dreams strongly reduced subjectiveness [18].

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