Out-of-the-Body Experiences

Implications for a Theory of Psychosis

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Chapter 6
Dissociation of arousal in the laboratory II: EEG data

Introductory remarks

Chapters 3 to 5 put forward a theory of OBEs according to which they are a phenomenon of sleep. The particular type of sleep proposed was that of Stage 1, whether ascending from the deeper stages or descending into them. I suggested that this proposal would explain the paradoxical fact remarked upon by Irwin (1985), that OBEs appeared to occur in states of either hyperarousal or low arousal, rather than in between. I explained those cases occurring in states of hyperarousal in terms of Oswald's (1961) description of 'sleep as a provoked reaction', i.e. a defensive response by the central nervous system to occasions of intolerable stress.

As mentioned at the start of the previous chapter, I developed this theory of OBEs after the start of the experiment I am describing, so the experiment was not planned in any way as a test of that theory. Nevertheless, the experiment yielded a considerable amount of data which can be considered of interest in the context of that theory.

One reason for this is the fact that the concept of arousal was central to what was being tested in the experiment. The hypothesis was that subjects reporting previous experience of one or more OBEs would be more likely to show a dissociation of arousal between the two hemispheres of the brain, given the particular conditions of the experiment, than would control subjects with no such prior experience.

Clearly one such dissociation of arousal which could manifest itself is for the right hemisphere of the brain to become more aroused than the left, which was the prediction being tested in the present experimental context.

As explained in the preceding chapter, the experimental procedure was designed to produce a state of mental and physical relaxation. So we might expect to have more success in looking retrospectively for cues that one or more subjects actually entered descending Stage 1 sleep, rather than sleep as a reaction to hyperarousal. However, as we shall see in the next chapter, there was at least one subject in which that latter phenomenon may have occurred.

Lateralisation of function between the cerebral hemispheres

Perhaps the most robust finding concerning lateralisation, at least in right-handed subjects, concerns the relative dominance of the left hemisphere for speech, and the cognitive functions that relate to it, such as sequential, analytical thought.[1]

There is convergent evidence for a degree of specialization of function between the two hemispheres from very different methodologies. In the field of EEG studies, for example, Robbins and McAdams (1974) reported that the right hemisphere showed more activity when subjects were asked to generate visual images of scenes shown, and the left more involvement when they were asked to compose a letter about the same scenes. Similarly, in a blood flow study using a radioactive isotope, Risberg *et al* (1975) reported relatively greater flow in the left hemisphere during a verbal analogies task and in the right hemisphere during a picture completion task.

In any consideration of hemispheric specialization one clearly has to guard against too simplistic an idea of functional localization. As Andreassi (1989)

[1] See, for example, Springer and Deutsch (1981) for a review.

put it: ‘In the final analysis, even though each hemisphere has its special functions, the entire brain must work as a unit in the processing of stimuli and the preparation of an optimal response.’

Similarly, Springer and Deutsch (1981), after reviewing evidence for hemispheric asymmetries from the widely differing methodologies of EEG, blood flow studies, metabolic scanning and nuclear magnetic resonance, comment: ‘Each of the measures [...] points to the involvement of many areas of the brain in even the simplest task. There are asymmetries in activity between the hemispheres, to be sure, but they can be very subtle, a fact that should lead us away from thinking about hemispheric specialization in overly simple terms.’

Nevertheless, as Claridge and Broks (1984) pointed out, ‘The hemispheres are indisputably separate functional-anatomic units – unlike intrahemispheric regions, which are relatively poorly specified.’ They suggest, therefore, that although there are no *a priori* reasons for expecting greater individual variability between hemispheres than within them, any pattern of variation between hemispheres should be relatively conspicuous.

From a practical perspective, the largely symmetrical nature of the hemispheres (from an anatomical as distinct from a functional point of view) means that with symmetrical, contralateral placement of electrodes, such as were used in the present experiment, one hemisphere is in a sense acting like a ‘matched control’ for the other—subject of course to the known ‘tonic’ asymmetries between hemispheres, such as the tendency for alpha amplitude to be slightly larger in the non-dominant hemisphere (Binnie, Rowan and Gutter 1982).

Out-of-the-body experiences and hemisphere function

The rationale for predicting that the occurrence of OBEs may be associated with a relative activation of the right hemisphere was as follows.

A consideration of the phenomenology of OBEs in relation to what is known of hemispheric specialization suggests that the right hemisphere might be relatively more active during such experiences than the left. The classical OBE would not appear to be a predominantly verbal or analytical experience; instead it seems often to be dominated by the contemplation of imagery, predominantly visual. When asked, subjects usually claim *post hoc* that their intellectual faculties were unimpaired during the OBE state. However, as Green (1968b) puts it, OBE subjects 'do not appear to feel inclined to engage in analytical thought; their attitude appears, generally, to be that of an alert but usually passive observer.'[2]

The detachment with which the OBE subject sometimes reports 'viewing' their own physical body, including when that body is ostensibly experiencing physical pain, might also be seen as implying a relative 'switching-off' of the logical, critical functions associated primarily with the left hemisphere.

In addition to these considerations, there is the fact that in right-handed people, who constitute the majority of the population, the right hemisphere seems to be preferentially implicated in visuo-spatial processing. (In left-handed people, the degree of specialization of the hemispheres is usually less.)

Fourier analysis

The main variable chosen for use in the present study of OBEs in the laboratory was the median frequency of the EEG spectrum. This is a measure which still appears not to be widely used in a research, as opposed to a clinical, context.

[2] Green 1968b, p.82.

For this reason, and because I believe it deserves to be more widely considered as a potentially useful tool in the investigation of arousal generally, I shall give some explanation of it.

As a preliminary to this explanation I will give a brief account of the mathematical technique known as Fourier analysis.

Fourier analysis is based on the idea that any complex wave form, such as the output from a single channel of an EEG machine, can be broken down into component waves of different frequencies. These component waves summate to produce the observed output from the channel.[3] The technique is named after the French mathematician and physicist Joseph Fourier (1768-1830), who was instrumental in developing it.

Fourier analysis enables one to compute the amplitude at all frequencies in a given range. 1 to 30 Hertz (cycles per second) was the range used in the present experiment.

Visually displayed, a plot of the values for amplitude over a certain range gives one a 'power spectrum', which may be thought of as an indication of the energy output of the cortex immediately below the electrode for all the frequencies within the prescribed range for a given 'epoch' of data.[4]

The median frequency of the EEG power spectrum

The median frequency can be calculated for either a power spectrum or an amplitude spectrum (amplitude being simply the square root of power). In my research, amplitude values rather than power values were used throughout.

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[3] See, for example, Binnie, Rowan and Gutter 1982.

[4] An 'epoch' in this context is a sample taken over a pre-determined length of time. Averaging over a fixed sample length in this way reduces the amount of 'noise' in the signal, i.e. moment-to-moment fluctuations due to factors irrelevant to what it is desired to measure.

The median frequency may be defined as the frequency which divides the area of the amplitude spectrum in half, so that 50% of this area lies above it and 50% below. Figure 6.1 gives an example taken from one of the subjects in my experiment. It represents the averaged amplitude spectrum for the six four-second data-blocks of the Control period (the three minutes before the start of the tape) for the dominant (left) hemisphere of one of the Control subjects. (Exactly half the area under the curve is to the left of the vertical line.) The prominent peak in the 8-9 Hertz region reflects the fact that this subject showed well-defined bursts of alpha waves in the paper record at this stage of the experiment.

It may be helpful at this point to give numerical definitions of the different 'bands' commonly used in EEG work. The following table lists, in ascending order, the parameters of the four bands as defined by the particular computer programme I was using. This was a programme originally developed by Chris Jordan of the Department of Anaesthesia, Northwick Park Hospital, for use in a surgical context, and I will refer to it as 'the Jordan programme'.

Table 1

Numerical definition of EEG bands

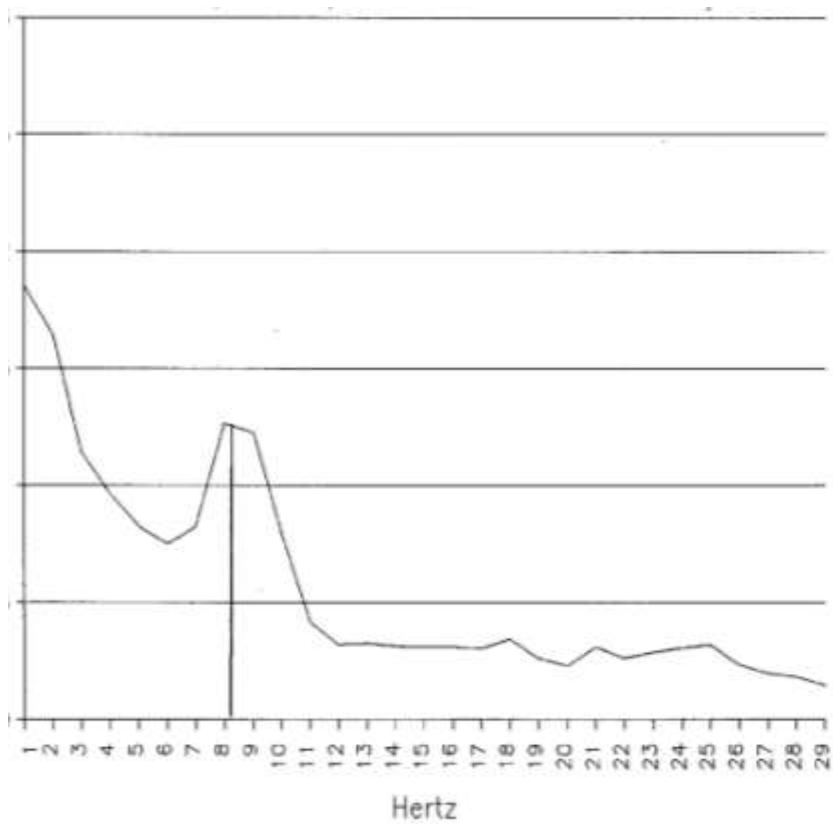
Name of band	Range of possible values in Hertz (cycles per second)
delta	1.0 – 3.75 Hertz
theta	4.0 – 7.75 Hertz
alpha	8.0 –12.75 Hertz
beta	13.0 – 29.75 Hertz

In the example shown below, the median frequency for the Control period, indicated by a vertical line, was 8.25 Hertz, i.e. within the alpha band.

Figure 6.1

Left Hemisphere Amplitude Spectrum

Control Period, Subject 40



The use of the median frequency as an index of arousal evolved during the 1980s for the practical purpose of quantifying and monitoring the level of anaesthesia during surgery.[5]

[5] Stoeckel, Schwilden, Lauven and Schüttler 1981.

Until its application by myself in the present experiment the use of this index of arousal seems to have been confined to the clinical setting.[6] Percentage of beta activity had been found to be a highly sensitive indicator of level of anaesthesia. But some risk was involved in relying on only 5% of total EEG activity, whereas the median frequency takes information from the total frequency range into consideration.

Eventually Schwilden *et al* (1983, 1987) settled on a threshold frequency of 5 Hertz as the maximum permissible for adequate anaesthesia. I.e. it was considered that it was not safe to proceed with surgical operations if the median frequency was greater than 5 Hertz. This value was decided upon by comparing it with other clinical signs; a median frequency value of 6 Hertz or more was considered by them to be compatible with awareness.

An advantage of the median frequency is that it is a proportional or ratio measure, rather than an absolute one, the ratio being that between the upper and lower frequency amplitudes of the power/amplitude spectrum. Ratio measures of various kinds have found wide application in EEG research. Notable examples are the power ratio in a given band as between the two hemispheres (Morgan *et al* 1971, Robbins and McAdam 1974), and power ratios between bands (Banquet and Sailhan 1976). To these we may add the criteria widely used to define the distinction between Stage 3 and Stage 4 sleep, namely the proportion of time for which deltawaves are visible in the paper record (Rechtschaffen and Kales 1968).

One advantage of ratio measures is that they help to normalise data with respect to individual differences of an extraneous nature. For example, as Davidson *et al* (1990) pointed out, individual differences in skull thickness may be expected to affect the absolute amplitude of the EEG. However, unless skull

[6] Schwilden, Schüttler and Stoeckel 1983; Schwilden and Stoeckel 1987.

thickness *differentially* affects absolute amplitude in different bands, we may expect the median frequency to be relatively uninfluenced by this extraneous factor.

The median frequency is capable of being directly related to level of arousal as follows: if the power/amplitude in a lower band, such as delta, increases while the power/amplitude in higher bands, such as beta, decreases or remains constant, the median frequency will fall. Conversely, if beta increases and delta falls or remains constant, the median frequency rises.

The significance of 'masking'

The qualification 'or remains constant' in the preceding paragraph is important for the following reason. In the early days of EEG research the relationship between different 'rhythms', or activity in different bands, was often thought of as reciprocal, since the appearance of one would often coincide with the disappearance of another. In particular, beta activity was often conceived as inversely related to alpha, since its appearance in the paper record of the EEG tended to coincide with alpha 'blocking' (Adrian and Matthews 1934).

However, already by the 1960s Cooper, Osselton and Shaw (1969) were pointing out, in a discussion of the analysis of complex wave patterns, that a component at one frequency may be masked by one at another frequency which had a larger amplitude. They wrote: 'As an example of the importance of masking, it was often thought that when alpha activity is blocked by attention it is replaced by "low voltage fast activity". It has recently been shown that the latter activity is present all the time, but is masked by the higher amplitude alpha rhythm [...]'

More recently Ray (1990) wrote: 'In our own laboratory, as well as in others, there is common skepticism toward the inverse alpha-beta assumption. For example, for various tasks we have found beta activity to increase or decrease with increases in alpha as well as to have no relationship' (McCarthy and Ray 1988).

One of the various possible amplitude relationships between the bands may be illustrated by Figure 6.2 below, which shows the averaged amplitude spectrum for the left hemisphere of same subject as Figure 6.1, but for the End period, i.e. the last three minutes of the Sound Phase, some thirty minutes after the data shown in Figure 6.1.

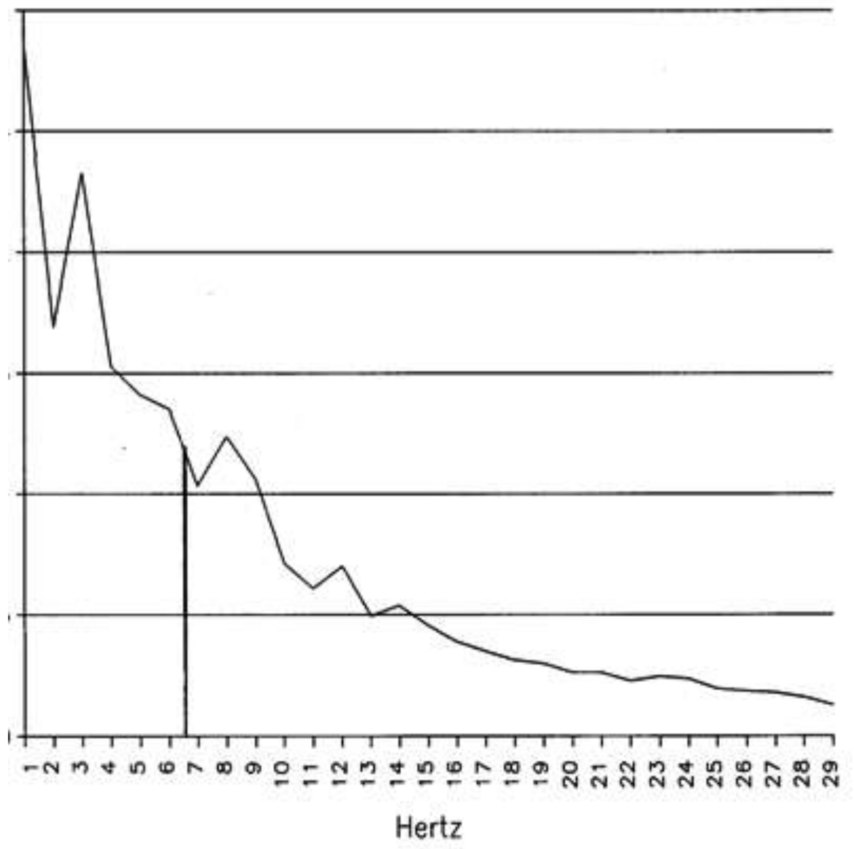
By this stage in the experiment the subject had, on his own admission, become drowsy and it will be seen that although the amplitude in the alpha range of 8-9 Hertz has remained approximately the same as in Figure 6.1, the amplitude in the theta and delta bands has noticeably increased, with a particularly prominent peak in the delta band at 3 Hertz. The result is that the median frequency has fallen from 8.25 to 6.50 Hertz. It is worth mentioning that delta waves were clearly visible from time to time in the paper record at this stage.

A plot of the moving average of this subject's median frequency over the complete course of the experiment will be shown in the next chapter.

Figure 6.2

Left Hemisphere Amplitude Spectrum,

End Period, Subject 40



The right hemisphere activation effect

The main purpose of the experiment was to look for individual differences in the effect of the Sound phase, and the preceding relaxation procedures, on differential arousal in the two hemispheres of the brain.

To establish a final baseline measurement of the subject's EEG immediately before the start of the experimental procedure, there was a Control period of three minutes, during which samples of data were collected every 30 seconds. These samplings lasted 4 seconds each, and gave six data points in all. The subject was instructed to relax with eyes open during this Control period.

To briefly recapitulate the various phases of the 30-minute experimental procedure following the Control period:

First 20 minutes:

- physical relaxation exercises
- followed by mental relaxation exercises

Final 10 minutes ('sound phase'):

- imagining floating up to the ceiling

To provide a picture of the progress of the median frequency in the two hemispheres over time the experimental period was divided into six 5-minute segments.

Figure 6.3

Average Median Frequency

by Group and Hemisphere, All Phases

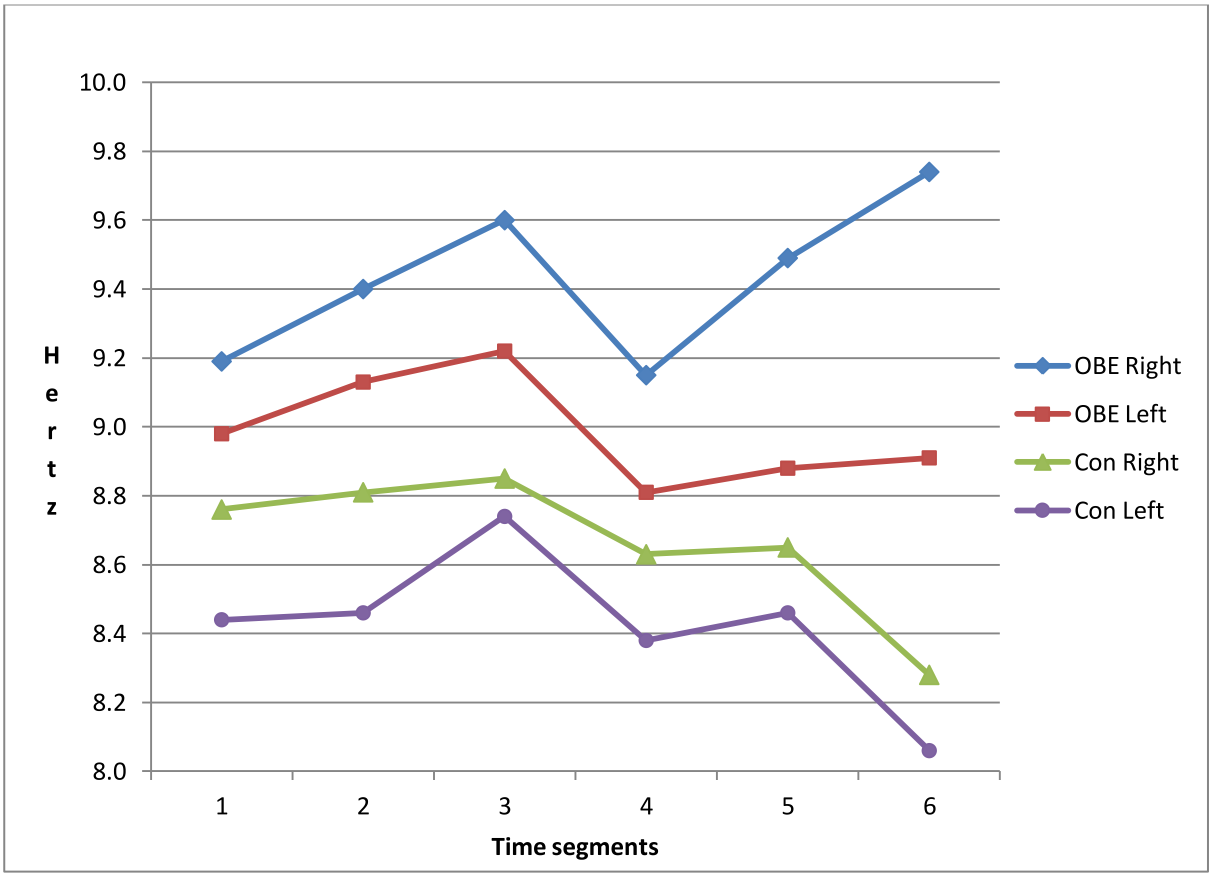


Figure 6.3 above represents the results of an analysis of the data in graphical form. Three members of the OBE group and three members of the Control group had to be omitted from this analysis due to missing data following artefact rejection. There are therefore 17 subjects in each group, as opposed to the full 20 available for various other analyses.

It will be seen that there is a tendency in both groups for median frequency to increase until the third segment, presumably reflecting the slightly arousing effect of the muscular tension-and-relaxation exercises following the quiescent Control period. Then there is a fairly steep drop for both hemispheres in both groups for Segment 4, which covers the purely mental relaxation phase. Segment 5, the first half of the sound phase, shows an increase, to a varying degree, in all four variables, presumably reflecting an increase in arousal due to the onset of the sound.

Finally, in Segment 6, the second half of the Sound phase, the Control group show a continuation of the temporarily interrupted decline in both hemispheres, whereas the OBErs show an acceleration, particularly in the right hemisphere, which displays a striking linear increase in median frequency over the last three data-points. As a result, whereas the two hemispheres of the Control group end up closer together than at the start of the experiments, those of the OBE group have noticeably diverged.

It may be noticed that the right hemisphere in each group is consistently above the left. However, this is likely to reflect the fact that in right-handed people *alpha* amplitude tends to be slightly larger on the right side of the brain than the left.[7] More interesting from our present point of is view is the fact that *both* hemispheres of the OBE group are consistently higher than those of the Control group. This is a finding that is compatible with the OBE group being

[7] Binnie, Rowan and Gutter 1982

in a consistently greater state of tonic arousal. This would fit well with the hypothesis that OBEs can be a phenomenon associated with extremely high arousal, leading to sleep as a provoked reaction, since people who are consistently in a state of higher than average arousal may be more likely to 'tip over' into such a reaction.

In the next chapter I will present some plots of the progress of the median frequency in individual subjects over the course of the experiment, and will examine to what extent they provide additional support for the theory I am putting forward.