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Functional Brain Imagery and Jungian Analytical Psychology: An Interesting Dance?

Leon Petchkovsky, Michael Petchkovsky, Philip Morris, Paul Dickson, Danielle T. Montgomery, Jonathan Dwyer, Patrick Burnett and Kristin Robertson-Gillam

Abstract

Jung's original neuroscience research project looked at the neurophysiological responses to the word association test (WAT) in an effort to understand 'complexes', those emotionally laden fixations that bother us all, and can be inferred from certain painful responses in the WAT. He measured breathing rates, skin conductance and electrocardiography, but there was no brain functional imaging technology available at the time. One hundred years later, a wide range of brain functional technologies are available, and this chapter describes two studies in which the WAT was performed under functional magnetic resonance imaging and quantitative electroencephalography conditions. In essence, a complexed response first activates the amygdala (many right-sided). This is followed in the next 3 s by bilateral brain activity in the anterior insula, the supplementary motor area and the dorsal cingulum; the premotor mirror neuron areas, the so-called resonance circuitry, which is central to mindfulness (awareness of self) and empathy (sense of the other), negotiations between self-awareness and the 'internal other', and has been well described by Dan Siegel. But over the following 2 s, activity shifts to the left hemisphere, seemingly the way the brain deals with a complex in the moment, possibly to dull the pain of the complexed response.

Keywords: Jungian psychology, complexes, fMRI, QEEG

1. Introduction

1.1 Jung on the complexes

It is one of life's ironies that Jungian analytical psychology, often regarded as the most starry-eyed of the psychoanalytic methods, had its beginnings, over 100 years ago, in what was essentially Jung's neuroscience research project (Jung [1]) in which he looked at neurophysiological responses to the word association test (WAT), in an effort to understand 'complexes', those emotionally laden fixations that bother us all, and can be inferred from certain painful responses in the WAT.

It is worth going back to Jung's original descriptions:

[complexes] are psychic entities which are outside the control of the conscious mind... always contain something like a conflict...are the 'sore spots', the bêtes noires, the 'skeletons in the cupboard' which we do not like to remember but still come back to mind unbidden in the most unwelcome fashion....experience shows that complexes are infinitely varied, yet careful comparison reveals a relatively small number of typical primary forms (Jung [1], pp. 528–529).

Jung's early WAT investigations led him to wonder about the role of complexes across a range of conditions, including psychosis, dissociative disorder and psychological trauma, through to everyday life:

...the average speed of the reactions and their qualities, was a relatively subsidiary result compared with the way in which the method was disturbed by the autonomous behaviour of the psyche....it was then that I discovered the feeling-toned complexes, which had always been registered before as failures to react (Jung [1], pp. 95).

1.2 A brief history of neuroscience research in analytical psychology

Jung and collaborators at the Burghölzli used the most advanced physiological psychology technology of the times, skin conductance (SC) or galvanic skin response (GSR), electrocardiography (ECG) and plethysmographic spirometry (measurement of breath rate and depth), to track the neurophysiological changes that accompanied complexed responses when patients performed the WAT.

When a person hears a word read-out from a standard list, and is asked to respond as quickly as possible with the first word that comes to mind, most responses tend to be bland and neutral. However, every so often there are long pauses, often with unusual behavioural and semantic features (the so-called complex indicators), and physiological disturbances (heart rate, breathing rate, skin conductance). Such responses typically organise around themes. From these responses, a 'map' of psychological 'hot spots' can be built. Jung called these affect-bound thematic nodes the 'complexes'. But more importantly, both he and Freud viewed complexed reactions as evidence of 'repression', a state in which the subject's experience collides with an internal opposition, generating internal conflict.

2. Functional brain imaging methods

Almost 100 years after Jung's research, there is now a range of brain imaging technologies which include functional magnetic resonance imaging (fMRI), QEEG, near-infrared spectroscopy (NIRS), positron emission tomography (PET), single-photon emission computed tomography (SPECT) and magnetoencephalography (MEG). The contributions of NIRS, PET and SPECT to anything of direct relevance to psychoanalytic practice have been modest for various reasons. The two most productive functional imaging modalities, in terms of giving deep insights into psychodynamic brain functions, are fMRI and QEEG.

2.1 MRI and fMRI

It takes 1–2 s for blood flow in an activated brain region to increase. More haemoglobin in its oxygenated form arrives in that area, and because it has different

magnetic properties to the deoxygenated form, this can be detected by the MRI scanner as magnetic signal variations, the so-called blood-oxygen-level dependent (BOLD) response. This allows functional maps to be constructed, with spatial resolutions as good as 1 cm^3 .

But temporal resolution is relatively poor, around 2 s. Since the early 1990s, fMRI has come to dominate brain mapping research because it does not require subjects to undergo surgery, be exposed to ionizing radiation or to take in radioactive substances.

2.2 Quantitative electroencephalography (QEEG)

The EEG is a collection of electrical signal patterns originating in the brain, recorded from a set of scalp electrodes. The so-called 10/20 placement is the most common electrode placement. Nineteen electrodes are applied to specific scalp sites, with a set of reference electrodes at each ear. QEEG differs from regular EEG because a range of algorithms have been developed over the last two decades to process the data and extract patterns that cannot be easily accessed visually from the 'resting' or 'background' EEG. The technology also allows one to administer a standard range of auditory and visual tasks and stimuli, which in turn generate EEG response patterns, the so-called event-related potentials (ERPs). This allows a closer look at the brain in action (see 'Event-Related Potentials (ERPs)' section) (see also Kropotov [2] and Thatcher [3]).

QEEG spatial resolution can be displayed by the low-resolution electromagnetic tomography (LORETA) process and technology developed by Pascual-Marqui et al. [4], based at the KEY Institute for Brain-Mind Research, University Hospital of Psychiatry Zurich, Switzerland, which is impressive (circa $1\text{--}2 \text{ cm}^3$) but not as good as that of fMRI ($1\text{--}6 \text{ mm}$). In his 1999 paper, Pascual-Marqui [5] reviews and compares several 'inverse problem' resolution methods and finds that the LORETA method is the most accurate. However, EEG temporal resolution is much better than that of fMRI in the millisecond range, and with fMRI, the initial 2-s poststimulus are unavailable, because it takes that long for the blood oxygenated signal to manifest in the brain, and from then on, temporal resolution of about 500 ms is about the best that can be obtained.

3. The fMRI of complexes as elicited by the WAT

This chapter provides a condensed account of our experimental studies. For the reader wanting more details, these are available in Petchkovsky et al. [6, 7]. Jung's word association test was performed under fMRI conditions by 15 normal subjects. Pooled complexed responses were contrasted against pooled neutrals.

3.1 Results

The scans were analysed using the Statistical Parametric Mapping program (see SPM-5 2009 url, 8). The complexed responses revealed a very strong pattern of bilaterally symmetrical activity in each hemisphere. Statistical significance of the results was well above the SPM-5 family-wise error (FWE) and false discovery rate (FDR) thresholds, described in SPM-5 2009 [8] with Z-scores ranging from 4.90 to 5.66, i.e. four or more standard deviations above the baseline expectation (a result with a Z-score of 3.9 or above has less than 1 chance in 10,000 of being accidental).

The initial left and right hemisphere symmetry of the generic complex response is well captured in this Drishti image, as developed by Limaye [9]. In each hemisphere, we can see the interactive pattern between mirror neuron sites (premotor mirror

neuron area and supplementary motor area), the conflict-monitoring cingulate gyrus and the anterior insula which tracks internal states but also communicates with midbrain limbic areas like the amygdala (to do with emotions). The BOLD responses accompanying ‘complexed’ activity are the strongest in the first 3 s (see **Figure 2**).

3.2 Complex versus neutral

One striking feature of the ‘complexed’ response pattern displayed above is the high level of interhemispheric symmetry in the first 3 s.

3.3 The complexed activation pattern

The complexed response pattern (see both **Figures 1** and **2**) includes [1] pre-motor mirror neuron areas that track ‘otherness’ (Brodmann area 9 and 44), [2] anterior insula on both sides (mediating proprioceptive and emotional self-awareness but also emotional empathy) and [3] dorsal cingulate gyrus (conflict-monitoring and self-monitoring processes, including conscious reflection about the ‘other’).

These are the sites described by Siegel and colleagues in 2007 and 2011 [10, 11] as the ‘resonance circuitry’. This serves both mindfulness (awareness of self) and empathy (sense of the other).

But our findings also show an interhemispheric dialogue. The left hemisphere over-rides the right within 3 s.

We can now add two further findings to this study:

1. Along with all the other findings, there was a very strong BOLD response seen in the first 3 s in the right dorsolateral prefrontal cortex RDLPFC; 7 voxels at 54,749. $Z = 5.06$! At that time that we could not find any research literature relating to the significance of this site. Since then, it has emerged that RDLPFC, in connection with the insula, is involved in salience, a state in which the attention is grabbed and shifted from default mode network activity, as it is when we activate a complex (see Sridharan et al. [12] and Goulden et al. [13]). RDLPFC is also active in fear-driven inhibitory responses (see Shackman et al. [14]). This correlates well with the increased response time in a complexed response.
2. The anterior insula interacts with both dorsal cingulate gyrus and mirror neuron areas and in turn influences reciprocally, midbrain limbic areas like the amygdala.

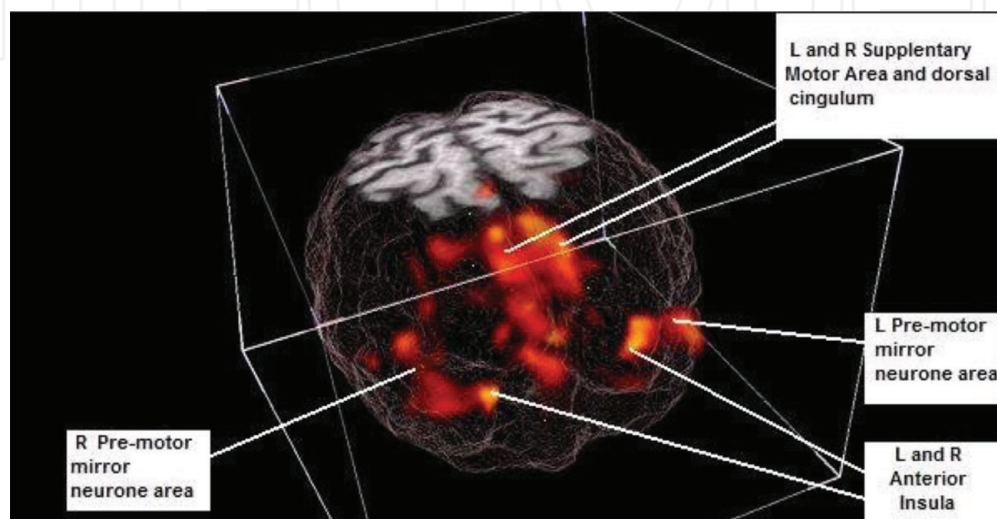


Figure 1.
The generic complexed response.

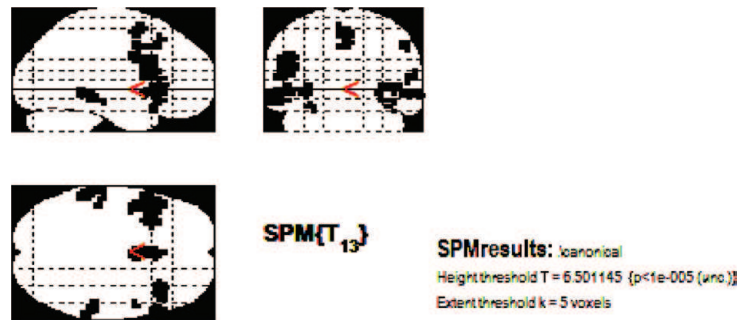


Figure 2.
First 3 s. Complex vs. neutral responses. SPM-5 images showing sagittal, coronal and transverse sections.

The interaction between the DCG and insula is very marked in states of social rejection and experiences of object loss. An easily readable overview of various studies that explore this interaction between the cingulate and insula is available in the December 1, 2012 issue of the *New Scientist* (see [15]). Interestingly, these two sites are also activated in states of physical pain, as described by Slavich et al. [16].

3.4 Complexed activity over time

Although fMRI temporal resolution is poor (around 2 s), spatial resolution is high (better than 1 mm^3). We can compensate somewhat by taking 2 s blocs overlapping by 1 s (as we have done in **Figure 3**), but we cannot break down the first 2 s to smaller time frames. The *much* higher temporal resolution of QEEG (milliseconds) helps us investigate the very earliest events, and we mention some preliminary findings further on in this text.

In the first 2 s, the activity is symmetrical. Presumably, a process of ‘internal conflict’ is active in each hemisphere, across a range of circuits (the ‘resonance circuits’) that mediate various aspects of ‘self’ and ‘others’ within each hemisphere. But soon after, the activity shifts to the left hemisphere.

When we analyse the data in 2-s fragments from the beginning, we see that the left hemispheric activity quickly becomes more prominent and right hemispheric much less so; until by the fifth second, only the left activity raises above FWE or FDR thresholds (see **Figure 3**).

The low temporal resolution of the BOLD fMRI response (some 2 s) does not allow us to make more detailed inferences about the very first 2 s. However, even within these limitations, we can say that the sequential patterns seen above suggest that in the initial 3 s, negotiation between sites subserving ‘self-’ awareness (medial sites like dorsal cingulum) and ‘other’ awareness (lateral prefrontal sites) occurs *within each* hemisphere and results in lateral prefrontal predominance (compare front to back activity in the ‘transverse section’ 0–2 with 1–3 and 2–4 s).

Also note that the medial prefrontal (SMA and dorsal cingulum) activity within *each* hemisphere, while strongest in the first 2 s, begins to fade relative to dorsolateral prefrontal activity. Compare the first ‘transverse section’ with the subsequent ones, and note how activity shifts to the left hemisphere and diminishes in the right one. Negotiation *between* left and right hemispheres results in left hemispheric hegemony. What is happening?

3.5 The ‘resonance circuits’

The ‘resonance circuitry’ pattern is the one that corresponds most strongly. Details of the literature review can be found in our Petchkovsky et al. [6].

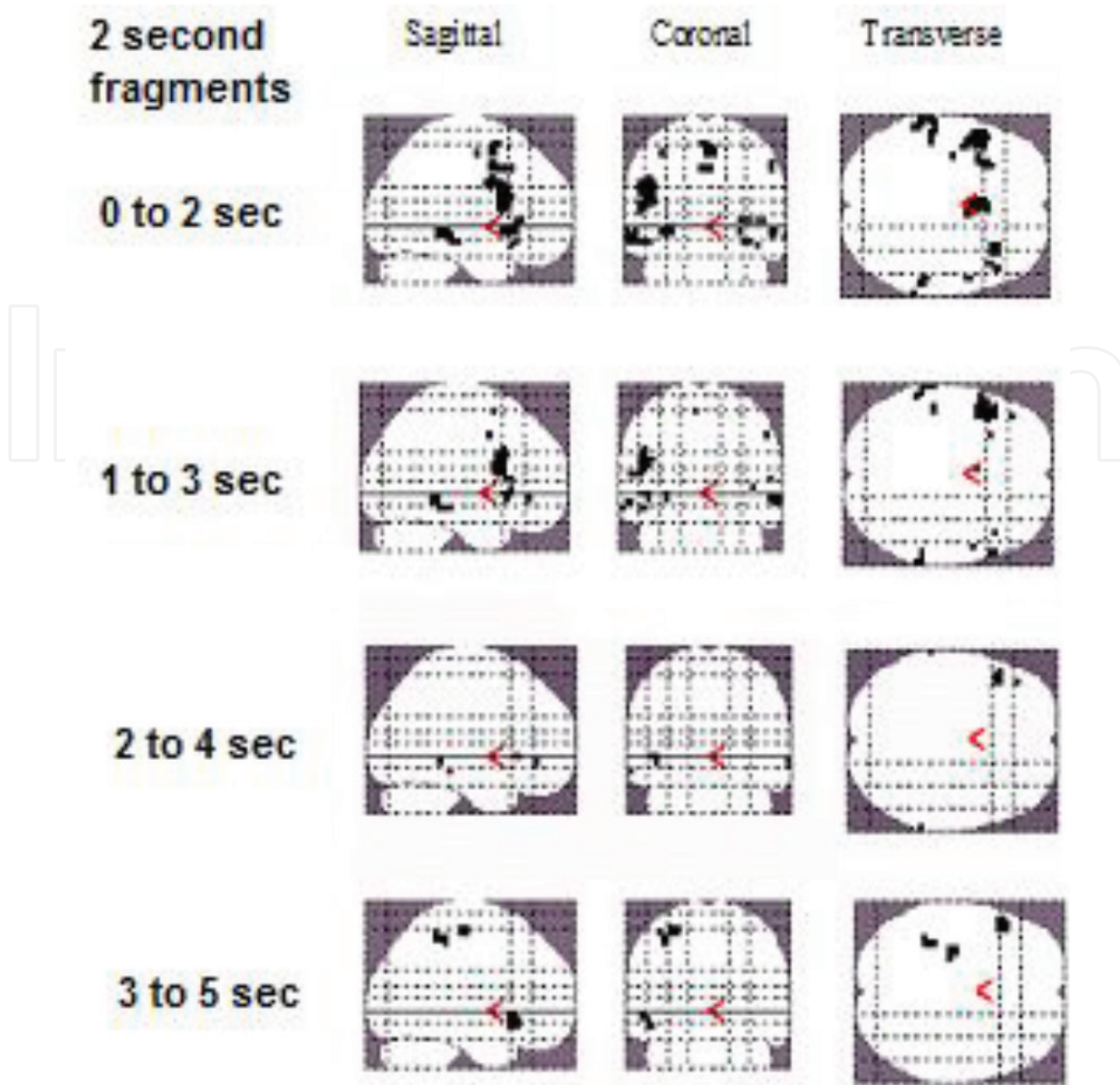


Figure 3.

Complexed versus neutral. SPM images, sagittal. Coronal and transverse, showing BOLD activity over the first 5 s.

Our findings suggest that what is being accessed is some representation of the ‘internal other’ which seems in conflict with the self. There is a sense in which all representations of ‘otherness’ have to be internal of course, since even mirror neuron activity is actually embedded in the observer’s circuitry.

Why does the ‘generic’ complex response initially show bilateral symmetry and then ‘resolve’ in left hemispheric dominance? We think this is actually a ‘pseudo-resolution’, the way the brain deals with a complex in the moment, possibly to dull the pain of the complexed response (as opposed to a real psychotherapeutic resolution, in which both left and right hemispheric experiences are tolerated, despite the pain, and worked with and hopefully come to a ‘transcendent function’ resolution). McGilchrist [17] argues that each hemisphere has its own distinctive mode of awareness or consciousness. In the first 2–3 years of life, the right hemisphere develops, processing incoming data (including proprioceptive ‘body field’) holistically and emotionally, mediating highly affect-loaded attachment and threat patterns. In the third year, left hemisphere circuitry begins to develop. Its process is linear, organised around language, logic and abstractions. In the affective domain, the left hemisphere is more curious, exploratory and danger-denying (the subject as predator). McGilchrist asserts that optimal mind states have to do with good inter-hemispheric communication, because a third more integrative mode of awareness

becomes possible. Pettigrew's [18] research on right versus left hemispheric function is also worth reading as a complement to the above.

4. Implications for psychotherapy

4.1 Mindfulness and empathy

The resonance circuits mediate mindfulness (awareness of self-concept and self-process) and empathy (awareness of the other, including the internal other). Much good psychotherapy involves establishing new patterns of relatedness especially in the domain of 'implicit relational knowing' as Lyons-Ruth points out [19].

4.2 Psychotherapy strategy: to resolve or tolerate the tension of internal conflict?

Although our fMRI findings suggest that the complex 'pseudo resolves' the conflict through the left brain dominance, there is also a deeper therapeutic opportunity (bringing awareness and compassion to work with the tension of opposites). The complex may continue to 'pseudo resolve' the tension in this fashion forever, unless the 'holding of the tension of opposites' that Jung recommended for psychotherapy can be done in a nurturing environment, leading to the emergence of a 'transcendent function' mediatory product beyond the terms of the original conflict.

In 1977, the Jungian Analyst Rossi [20] wrote that 'just as the cerebral hemispheres are in a continuous process of balancing and integrating each other's functions on a neurophysiological level, Jung describes a similar regulation'. Not all conflicts can be reduced to the left vs. right brain. Our findings also show that in the first 3 or so seconds, *within each* hemisphere, patterns associated with negotiations between the internal self and internal other can be seen.

5. QEEG findings in the WAT responses

A new research project, the QEEG responses to the WAT (eight subjects thus far), is also being worked on, but we need at least another six to eight subjects for a reliable pilot study. However, QEEG allows us to look in detail at the first 500 ms that are unavailable to fMRI, because of QEEG's much better time resolution (milliseconds). We are releasing a 'preview' here (**Figure 4**).

We noted in our preliminary examination of the QEEG results that within the first 60 ms, complexed responses begin to manifest as activity in the right middle temporal region. LORETA imaging struggles to locate amygdalar activity precisely, because it is so deep in the brain, but amygdalar activation can be inferred because right middle temporal activity is typically seen when the right hemispheric amygdala is activated by a stressful event, (in this case, the complexed response to a painful stimulus word). But from 150 ms onwards, there is an activation of the default mode network (DMN, anterior cingulate and precuneus), which mediates a background sense of self.

We suspected, in our published fMRI study, that the right amygdala and DMN had to be involved. The QEEG findings confirm this, allowing us to see what could not be detected by fMRI. Amygdalar and DMN activity predominate only in the very earliest phase of the response.

However, from about 1000 ms onwards, QEEG findings are very similar to what was found in the fMRI study. The left hemispheric activity (probably defensive in nature) gradually predominates over right over the next 3 s.

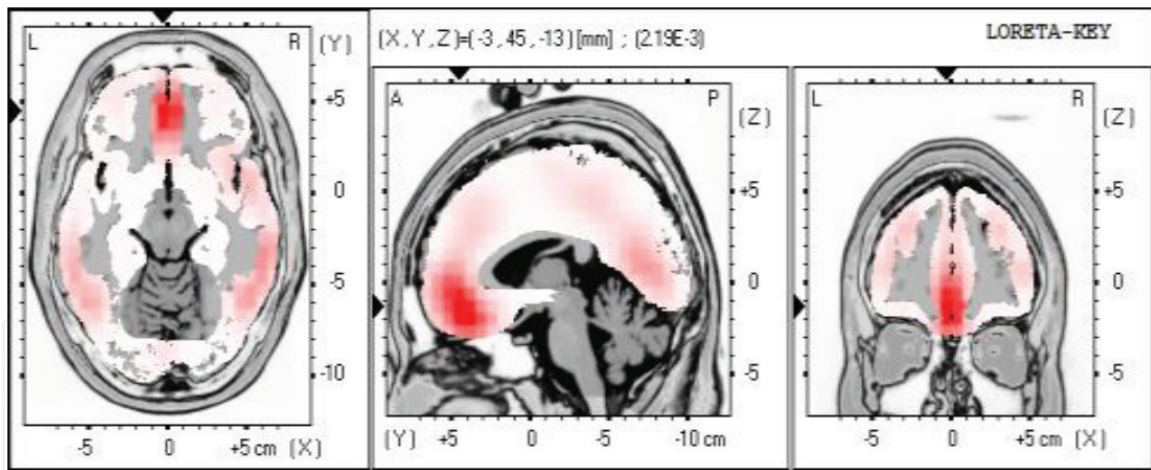


Figure 4.

The first 200 ms. EEG LORETA image of DMN activity smeared within the first 200 ms of the complexed response. See activation of the cingulate gyrus, precuneus and angular gyrus.

This study sets the basis for further research:

- i. QEEG studies (with their finer temporal resolution) of specific as opposed to generic complexed responses in normal subjects
- ii. QEEG and fMRI studies of complexed responses in other conditions, like schizophrenia, PTSD, developmental trauma disorders and disorders of self-organisation

5.1 A clinical example illustrating the usefulness of QEEG in psychotherapy efficacy research

We finish this discussion with an example of how brain functional imaging can facilitate the understanding and tracking of a psychotherapy process. While it is true that Jung encouraged the use of a range of creative techniques, including singing, the following account is not specific to Jungian therapy alone.

A group of 32 treatment-resistant outpatients suffering from chronic depression with anxious/agitated features were offered an intensive 8-week-long music therapy programme involving choir work by my music therapist colleague Robertson-Gillam et al. [21]. QEEGs were performed before and after, using the Mitsar WinEEG program. This included the visual cognitive performance task (VCPT), which we used to elicit event-related potentials, indicators of brain function. The VCPT task is a GoNoGo task. The three types of visual stimuli presented in this task are pictures with animals, pictures with plants and pictures with peoples. The subject presses a button when an animal picture follows a previous animal picture but refrains if the first animal picture is followed by a plant or if one plant picture follows another. Every so often however, a plant picture is followed by a picture of a human and a bell-like noise. This is the so-called 'novel' stimulus. The component of the ERP wave response to this is called P3a or P3Nov wave. The patients had abnormally high responses to the novel stimuli during QEEG acquisition. This correlated with their hypervigilance and excessive responses to stress.

After 8 weeks of the music therapy, their P3a or novelty response had returned to normal (see (a) and (b) in the diagram). It was also possible to get a 3-D image of the location of the abnormal activity in the mid-cingulate gyrus region (see LORETA image (c)) (**Figure 5**).

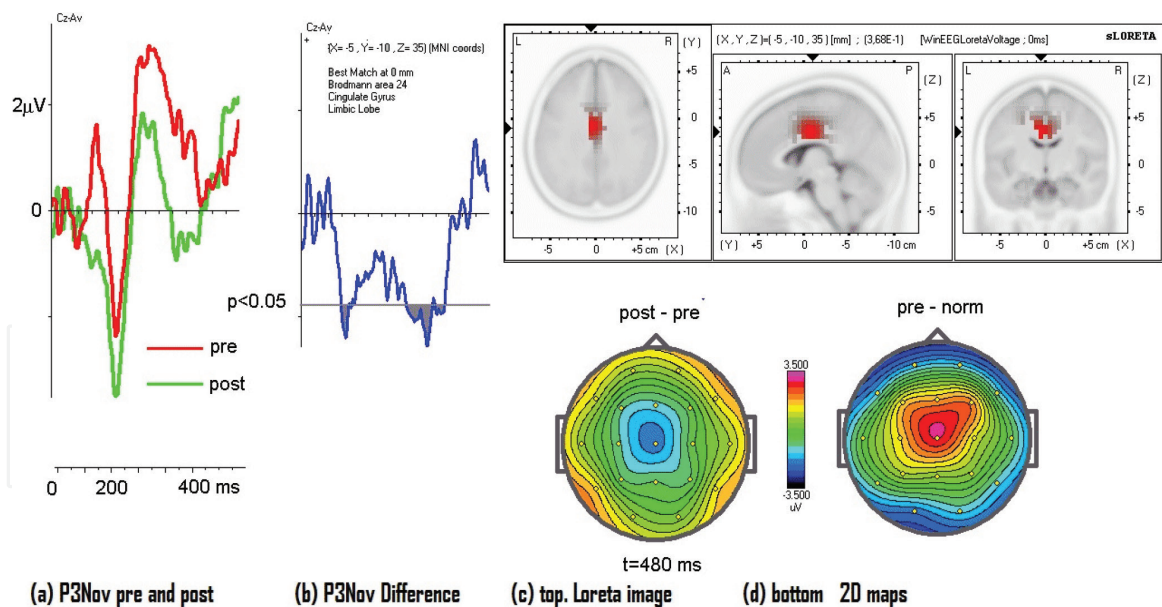


Figure 5.
 QEEG P3a response normalization in a depressive group.

Individual QEEG patterns are extremely constant, usually with very little change over decades, as noted by QEEG neuroscientist Kropotov [2–4]. The rapid change we see here tells us that something major has occurred in the way the patients’ brain processes life events.

5.2 Schizophrenia and WAT and fMRI and QEEG

Our very preliminary QEEG findings in three schizophrenic patients doing the WAT suggest that for them, in a complexed response, the right insular/cingulate activity persists for several seconds, accompanied by the right temporal activity (auditory hallucinatory processes?). This matches the patient’s experience. QEEG and fMRI studies of responses to the WAT, with sufficient subject numbers (both normal and patients with schizophrenia), are desperately needed. This will deepen our understanding and opens up a range of important assessments and diagnostic possibilities.

6. Conclusion

Science and the transcendental are seemingly incompatible. But they represent two of the deepest currents of human existence. The combination of these two perspectives makes analytical psychological so worthwhile. This field stands to benefit enormously from further engagement with neuroscience and especially its active research components.

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