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fMRI responses to Jung's Word Association Test: implications for theory, treatment and research[1]

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Abstract: Jung's Word Association Test was performed under fMRI conditions by 12 normal subjects. Pooled complexed responses were contrasted against pooled neutral ones. The fMRI activation pattern of this generic 'complexed response' was very strong (corrected Z scores ranging from 4.90 to 5.69). The activation pattern in each hemisphere includes mirror neurone areas that track 'otherness' (perspectival empathy), anterior insula (both self-awareness and emotional empathy), and cingulated gyrus (self-awareness and conflict-monitoring). These are the sites described by Siegel and colleagues as the 'resonance circuitry' in the brain which is central to *mindfulness* (awareness of self) and *empathy* (sense of the other), negotiations between self awareness and the 'internal other'. But there is also an interhemispheric dialogue. Within 3 seconds, the left hemisphere over-rides the right (at least in our normal subjects).

Mindfulness and empathy are central to good psychotherapy, and complexes can be windows of opportunity if left-brain hegemony is resisted. This study sets foundations for further research: (i) QEEG studies (with their finer temporal resolution) of complexed responses in normal subjects (ii) QEEG and fMRI studies of complexed responses in other conditions, like schizophrenia, PTSD, disorders of self organization.

Key words: fMRI, internal conflict, Iain McGilchrist, left hemisphere, psychological complexes, resonance circuit, right hemisphere, Dan Siegel, transcendent function

Jung on the complexes

It is worth going back to Jung's original descriptions. He was impressed by the way complexes seemed to over-ride volition and conscious intention.

> [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

[1] This paper has been adapted for a non-technical psychoanalytic readership. A technically detailed account of the procedure and findings is available in a paper published in the US *China Journal of Medical Sciences* (Petchkovsky et al 2011).

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> 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 1921, paras. 923–27)

Jung's early Word Association Test investigations in schizophrenia revealed affective as well as cognitive dimensions, leading him to wonder about the role of complexes across a spectrum of conditions, ranging from psychosis, dissociative disorder, psychological trauma, through to everyday life.

> [T]he 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* . . . fundamentally there is no difference in principle between a fragmentary personality and a complex. . . whether such small psychic fragments are also capable of a consciousness of their own is still an unanswered question.
>
> *. . . Dream psychology shows us as plainly as could be wished how complexes appear in personified form. . . We observe the same phenomenon in certain psychoses when the complexes get 'loud' and appear as 'voices' having a thoroughly personal character. . .*
>
> *. . . the aetiology of their origin is frequently a so-called trauma. . . . . .[or]. . .a moral conflict. (ibid., para.* 204*) . . . complexes are in truth the living units of the unconscious psyche. . ..that is why Freud became the real discoverer of the unconscious in psychology. . .the via regia to the unconscious, however, is not the dream, but the complex, which is the architect of the dreams and symptoms.*
>
> (Jung 1934, paras. 196, 202, 203 and 210 respectively)

The notion of a 'fragmentary personality' implies an internal 'otherness' at odds with the ego (which Jung regarded as yet another complex, albeit the central one). This in turn implies a process of internal conflict. However, the balance between these tensions varies. By and large, the ego 'wins' in the normal subject, but in conditions like schizophrenia, an activated complex can dominate consciousness. Since our investigation looked at *normal* subjects only we might expect to find evidence of the disturbance introduced by the internal conflict being overcome by the ego as in Jung's normal subjects.

A brief history of neuroscience research in analytical psychology

It is one of life's ironies that analytical psychology, often regarded as the most starry-eyed of the psychoanalytic methods, had its beginnings, over 100 years

ago, in what was essentially a neuroscience project, although, because brain functional imaging technology was not available at the time, Jung (1907–8) had to content himself with measuring the peripheral physiological responses that reflect central activities. Jung and his collaborators at the Burghölzli, trying to track the neurophysiological changes that accompanied complexed responses when patients performed the Word Association Test (WAT), used the most advanced physiological psychology technology of the times: Skin Conductance (SC) or Galvanic Skin Response (GSR), Electrocardiography ECG, and plethysmographic spirometric (measurement of breath rate and depth). Jung, with his Word Association Test (WAT), and Freud with his 'free association' technique, examined the associative processes in their patients' inner lives. The inferences they drew from their findings helped build psychoanalytic theory. Freud acknowledged the contributions of Jung's WAT research to psychoanalytic theory in his discussion of dream interpretation in the 1915 Introductory Lectures (Freud 1915–16, p. 109).

As we know, Jung noticed that when a person presented with a word from a standard list is asked to respond as quickly as possible with the first word that comes to mind, most responses tend to be bland and neutral, but 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 organize 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.

Jung's neuroscientific approach appealed to the pragmatic US Zeitgeist, and he was invited to lecture at Clark University in 1909. Jung considered that 'the association experiment and the psychogalvanic experiment were chiefly responsible for my reputation in America' (Jung 1963, p. 120).

Jung stopped routine use of the WAT and neurophysiological evaluations in his private analytic practice because his vast experience and highly developed intuition made this redundant. It took another 80 years before any further serious research in the WAT was attempted. Jeffrey Satinover, in the early 80s, tried to look at the neurobiological underpinnings of the complexes, using newly developed Quantitative ElectroEncephaloGraph (QEEG) techniques (Satinover 2006). This, sadly, proved inconclusive because QEEG and Event related Potential (ERP) computerized data analysis was then in its infancy. And functional Magnetic Resonance Imaging (fMRI), another method for imaging brain function, would take another 20 years to develop to the point where it could be accessed routinely by researchers.

A search of the analytical psychology literature revealed few publications bringing research neuropsychology methodology to the field. Of note were 2 papers. The first (from Seoul in Korea: Yong-Wook Shin et al. 2005) found that,

paradoxically, the activation of a complex not only enhanced the attention of subjects, but improved their performance on an implicit learning task. This finding resonates with ours. Our 'complexed' responses showed both activation of the head of the caudate nucleus (indicating captivated attention) and right hemispheric regions involved in implicit learning (see the 'Left and Right Brain' discussion section further). The second study (from Milan in Italy: Vezzoli et al. 2007) did not use brain imaging technology, but tracked changes in the inter-relational patterns of complexes during therapy. The present fMRI study does not allow us to describe the inter-relational patterns of complexes, but further research, including QEEG work, may allow us to track the neurophysiological correlates of complex pattern changes.

Complexes and the developmental trajectory

Theodor Ziehen, one of Germany's first child psychiatrists, is credited with having coined the term 'complex' in 1898. Jung expanded it in his formulation 'feeling-toned complex of ideas' to refer to the 'hot spots' that his Word Association Test elicited. Jung formulated that the core of any complex is archetypal, and that while, complexes can be conscious, partly conscious, or unconscious, in all cases they act as *splinter psyches* (Jung 1934, para. 203) and are largely painful (ibid., para. 207). But after all these years, the pathogenesis of the complexes is still very unclear. How does any particular archetype unpack in the individual's ontogeny? Obviously, traumatic events could leave their permanent marks in the form of complexes (as in the fearful associative responses in various forms of PTSD). But the timing of traumas within the developmental trajectory was largely left out of the account (with the exception of Oedipal dynamics). Contemporary developmental research (not available to Jung) reminds us that socio-emotional brain patternings are probably laid down as early as in the uterus, and various forms of neglect or empathic mismatching (which might not be all that traumatic to an adult) can produce radical and life long damage in a baby or infant, as can pathological attachment dynamics of various kinds, and disorders of self-organization and function. Furthermore, developmental possibilities that depend on the establishment of a prior functional base would be thwarted. (The diminished capacity for self-awareness that we see in alexithymia and various borderline conditions would be examples).

There is a large literature on the subject, both within contemporary psychoanalysis and development psychology and neuroscience. A good account of developmental aspects of analytical psychology (reviewing contributions including those of Bowlby, Fonagy, Knox, Bucci, Schore, Siegel) can be found in Cambray and Carter's *Analytical Psychology: Contemporary Perspectives in Jungian Analysis* (2004) but this paper is not the place to review them

in detail. Suffice it to say that these early developmental patternings are non-verbal, implicit, possibly pre-symbolic, but we know that they must nevertheless impact on Complexed Word Association responses in various ways. For instance, complexed responses are often emotionally painful, and the brain circuitry of emotion is non-verbal.

The Word Association Test necessarily relies on words, and hence on the left hemispheric function. But left hemispheric development in humans only begins in the 2nd or 3rd years of life. This does not mean that complexes cannot emerge in the first 2 or 3 years of life, of course. In fact, the research findings of Allan Schore (Schore 2003) strongly suggest that during this time, implicit/procedural affective patterns or programmings are laid down in the right hemisphere of the infant brain, in interaction with the care-giver, often in the form of 'attachment styles', and continue to have an overwhelming effect on behaviour and object choices for the rest of our lives. Developmental or 'Complex' PTSD (Herman 1997), an earlier formulation for Reactive Attachment Disorder, takes into account the fact that trauma has different effects depending on the developmental stage of the individual at the time it occurs. Adult Post Traumatic Stress Disorder clearly generates complexes of a kind, even if the individual's early development has been 'good enough'. The DSM-IV check-list for PTSD specifies this. For instance, 'flash-backs', the re-living of traumatic events, are triggered off by associative prompts in the environment. Clearly there is some overlap here between adult PTSD and 'complex' or developmental PTSD, and a complexed response uses early fearful right hemisphere 'programmes' as a basis. The specifics of biographical events provide the rest. Our findings support this. We noted that right hemispheric regions (including limbic/anterior insula) are activated early in the complexed response. And there are some similarities between our 'complex responses' and what is seen in imaging studies in PTSD, Borderline conditions, and attachment states (details in Petchkovsky et al 2011). But further brain imaging studies to differentiate between 'ordinary' and PTSD-type complexed responses are required.

Method

Subjects

These were 13 volunteers: 7 males, 6 females, 12 R handed, 1 L handed, ages 26 to 63, all adult mental health professionals (psychologists, psychiatrists, psychotherapists, counsellors, Jungian analysts) affiliated with the Australian and New Zealand Society of Jungian Analysts (ANZSJA). Two volunteers repeated the test after a 12 month interval. One scan had to be discarded because dental fillings interfered with the imagery, thus yielding only 14 scans.

Recruitment and ethics

Recruitment was by word of mouth invitations to ANZSJA members and affiliates, e-mail invitations via the ANZSJA mailing list, public announcements at ANZSJA AGMs (2005, 2006) and ANZSJA-sponsored Professional Development Seminars.

Clearance was obtained from the Ethics Committees of ANZSJA, the University of Queensland, and the Wesley Hospital Brisbane (the site of the fMRI Unit). Confidentiality measures were in place.

In a pre-procedure interview, subjects were given 'Information for Volunteers' forms, and Metals Check and Interim Medical Examination as prescribed by Wesley Hospital fMRI protocols. Written Informed Consent was obtained after the procedure had been fully explained.

Investigators were concerned about the unsettling nature of eliciting 'complexed' responses. Volunteers could have, on request, intensive de-briefing sessions with a choice of senior consultants.

Technical procedures

The primary form of the fMRI process relies on *contrasting* blood-oxygen-level-dependent (BOLD) signals between 2 conditions, the 'test' condition (in this case 'complexed' responses) versus the 'baseline' condition ('neutral' responses) to measure oxygenated blood flow (and hence metabolic activity) in brain regions that get activated in the 'complexed' response.

The WAT was performed at the Wesley Hospital Brisbane using a 4 Tesla Bruker Medspec system. The fMRI process requires each subject to hold their head very still throughout. Our fMRI Unit technical advisers stressed that vocalization can spoil imaging. Furthermore, the noise level in the magnet is very high. We therefore modified the classical procedure so that words were presented visually.

Volunteers were told that every 20 seconds a word from a standard list of 100 words would appear on a video screen (in two blocks of 50 words each with a 5 minute rest period because the fMRI machine can only operate continuously for about 20 minutes before overheating). And instead of vocalizing their response, volunteers would press a finger-button just as soon as they had completed 'saying' their response mentally, then hand-write the response word on a moving scroll. Volunteers received a prior 5 minute practice session. Response times were measured. Two lots of 339 volumes (36 slices per volume) were acquired for each scan.

It is important to note that visual presentation of the WAT words, in the isolation of the fMRI chamber, reduced the felt presence of the 'interlocutor' significantly. This is actually a benefit for the experimental paradigm, both because it reduced the independent variables that go with the interlocutor, and pushed the focus much more on *internal* process in the subject, as opposed to interaction with the experimenter.

The Standard English version Zurich Institute 100 Word WAT List (C. G. Jung Institute 1974) was used. An English translation of Kast's WAT Guidelines (Kast 1980) and Meier's text on the WAT (Meier 1984) informed procedure.

Complex indicators, as detailed in the WAT Guidelines (ibid.) include;

1. Any reaction time 0.4 sec greater than the Median (or so-called 'probable mean', being the average between the 50th and 51st fastest within the 100 ranked responses) (see Jung 1904-7/1973, para. 571).
2. Incorrect reproductions on repeat WAT (not done here because of logistical constraints)
3. Semantic Indicators

    a. No reaction
    b. Repetition of stimulus word
    c. 'clang' reactions (e.g., big-pig)
    d. Disconnected reactions. E.g., subject gives the name of an object in the room unconnected with the stimulus word
    e. Responding with several words
    f. Neologisms, colloquialisms, profanities
    g. Stereotypies (use of the same response repeatedly)

4. Behavioural indicators. (These could not be observed effectively while the subject was in the magnet, but were observed in the post-fMRI interview).

    a. Mimic, movement, laughter
    b. Stuttering or mispronunciation

5. Self-reported complexes

Identifying and selecting complexed responses in individuals

After each session, investigator discussed responses with subject, marked responses subject felt were disturbing, identified semantic 'complex indicators' (as described in the Zurich WAT protocol) and invited further comment.

Within each WAT response, we identified several variably overlapping groups.

- Time Delay (TD) Group (0.4 seconds above Median)
- Self Reported Complex (SR) Group
- Semantic Indicators Group (SI)
- Pooled (Complex) or 'Generic' set. The sum of TD, SR and SI responses
- Neutral (Simple) Group. All remaining responses below median time, excluding any response that followed immediately after either a TD or SR response since a strong complexed response can sometimes persevere to the next word presentation.

Interview responses, together with the response time data, allowed us to compile a reliable list of complexed responses. All complexed responses were gathered and contrasted with all neutral ones for the entire group, allowing us to map a 'generic complex response'.

Results

The scans were analysed using the Statistical Parametric Mapping Programme (SPM5 2009). The complexed responses revealed a very strong pattern of bilaterally symmetrical activity in each hemisphere. A 't' Test was applied to the 'Complex versus Neutral' comparison. Statistical significance of the results was well above the SPM-5 Family Wise Error (FWE) and False Discovery Rate (FDR) thresholds, with Z-scores ranging from 4.90 to 5.66; i.e. 4 or more Standard Deviations above baseline expectation (a result with a Z score of 3.9 or above has less than 1 chance in 10 thousand of being accidental, see Table 1).

The initial Left and Right Hemisphere symmetry of the generic complex response is well captured in this Drishti image (Limaye 2006). In each hemisphere, we can see the interactive pattern between mirror neurone sites (Pre-motor Mirror Neurone Area and Supplementary Motor Area), the conflict monitoring Cingulate Gyrus, and the Anterior Insula which tracks internal states, but also communicates with mid-brain limbic areas like the Amygdala (to do with emotions). The details follow below.

The BOLD responses accompanying 'complexed' activity are strongest in the first 3 seconds (see Figure 2).

Explanatory notes: The SPM-5 programme produces a diagram which attempts to deal with the difficulties of representing a complex 3 dimensional structure on a 2 dimentional plane. It does so by using 3 'sections'. The sagittal section (top left) views the brain from the side. The coronal section (top right) looks at the brain from the front as if the front had been sliced off. The Transverse section (bottom left) looks at the brain from above, as if the top of the brain had been removed.

The transverse Axis is X, the front-to-back one is Y, and the vertical one is Z. These co-ordinates allow SPM to specify in millimetres *where* each response site is located in the brain space. Our SPM-5 analysis resolved the 3-D brain image into Voxels (3.6 by 3.6 by 3.6 mm cubes), which are specified by X, Y, Z co-ordinates. This allows the programme to generate sets of X, Y, Z co-ordinates for each active area.

The red arrow at the centre of each 'section' is the point 0,0,0. Readers wishing to access X, Y, Z co-ordinates for the areas appearing in the SPM images above and listed below will find this in Petchkovsky et al 2011.

One striking feature of the response pattern displayed above is the high level of interhemispheric symmetry in the first 3 seconds.

Table 1. As previously mentioned, the results show a very strong statistical salience. In order of decreasing statistical salience (Z scores ranging from 5.69 to 4.50), the following BOLD responses above the FWE and FDR thresholds are seen.

Z = 5.69	101 voxels in Left Ventrolateral Prefrontal Brodmann areas 9 and 44. (Mirror neurone sites and linguistic expressive sites)
Z = 5.46	40 voxels in the Left superior and middle temporal region. (mirror neurone and linguistic processing sites)
Z = 5.24	58 voxels in the Left anterior Insula (interoceptive/self-awareness site)
Z = 5.13	21 voxels in Right Supplementary Motor Area SMA and Dorsal cingulate gyrus. (Supra-ordinate mirror neurone sites and conflict-monitoring/self-monitoring sites).
Z = 5.06	7 voxels in the Right Dorso Lateral Prefrontal Cortex (DLPFC) at 54, 7, 49. There is no research literature relating to the significance of this site.
Z = 5.05	22 voxels in the Right Middle Temporal Region (homologue to the contralateral Left Temporal Area)
Z = 5.02	32 voxels in the Right Anterior Insula (homologue of the Left Interoceptive/Self Awareness site)
Z = 4.93	28 voxels in the Left SMA and Dorsal Cingulum (Z = 4.93) (homologue to the corresponding Right area to do with conflict-monitoring/self-monitoring)
Z = 4.90	20 voxels in the Right Ventrolateral Prefrontal Brodmann areas 9 and 44. (Mirror neurone sites and linguistic expressive sites)
Z = 4.50	12 voxels in the Left head of caudate. This region is active when attention is captivated by an internal process (obsessional states are one example).

The complexed activation pattern

The complexed response pattern (see both Figure 1 and Figure 2) includes (1) mirror neurone 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').

The anterior Insula interacts with both Dorsal Cingulate Gyrus and Mirror Neurone areas, and in turn influences, reciprocally, mid-brain limbic areas like the amygdala. The interaction between 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 Cingulate and Insula is available in the 1st December 2012 issue of *New Scientist* (Raffensperger 2012). Interestingly, these two sites are also activated in states of physical pain (see also Slavich et al 2010).

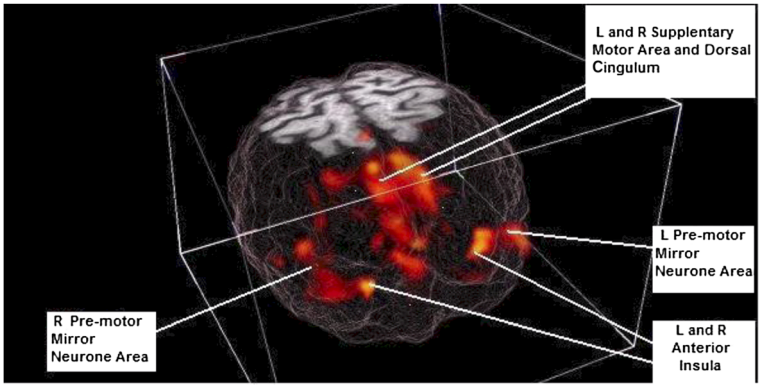

Fig. 1. The generic complexed response

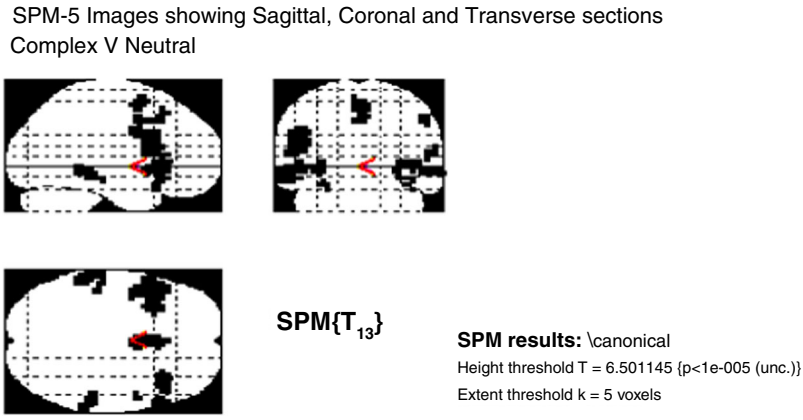

Fig. 2. First 3 seconds

The pattern of the generic 'complexed response' seems to use that combination of brain areas described by Siegel and colleagues (Siegel 2007) as the 'Resonance Circuitry' in the brain central to mindfulness (awareness of self) and empathy (sense of the other). The 'Resonance Circuitry' is discussed in greater detail further in this paper, but in essence, comprises

(1) Medial Prefrontal Cortical activity (like our Dorsal Cingulum findings) associated with self-referential and internal comparison processes;
(2) Lateral Prefrontal Cortical activity (like our peri-Broca's Brodmann area 9 and 44 findings) which have more to do with reference to 'others', and

(3) the Insula (which lights up in our findings as well), which tracks self-experience in the moment, but also seems to mediate between the other two areas and lower mid-brain ones like the amygdala and hind-brain ones like the vagal and sympathetic nuclei and tracts (areas to do with the arousal level and emotions aroused by any particular experience). As we pointed out earlier, DCG and Anterior Insula are also very active in states of emotional pain.

Neutral responses

It is important to realize that when the SPM-5 analysis contrasts complexed versus neutral responses, the features common to both conditions 'cancel out'. Therefore, to obtain an independent fMRI pattern of neutral activity, the neutral responses to the WAT have to be contrasted against something else again. We pulled out the first scan volume from the 20 second bloc time for every neutral response, and contrasted this against the last volume, reasoning that because neutral response time was so brief (less than 0.8 sec) the last 3 seconds or so spent waiting for the next word to come up might give us a fairly bland background condition for purposes of contrast.

Neutral responses showed activity in the cerebellum (mainly Right side, and probably to do with 'efferent tracking' of executive responses; i.e. tracking the generation of a new word in response to the stimulus word), Left Broca's (verbal expressive) and temporo-parietal (verbal searching and associative) regions. This is what we would expect in a word search and response task. This (including the cerebellar activity) was similar to the incidental findings of Simmons et al (2008), who looked at neutral word association responses as part of a larger study in mental simulations.

Complexed activity over time

Whereas fMRI spatial resolution is high (better than 1 cubic mm), temporal resolution is poor (around 2 seconds). We can compensate somewhat by taking 2 second blocs overlapping by one second (as we have done in Figure 3) but we cannot break down the first 2 seconds to smaller time frames. The *much* higher temporal resolution of QEEG (Milliseconds) will help us investigate the very earliest events.

In the first two seconds, the activity we see 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 'other' within each hemisphere. Very soon however, activity shifts to the left hemisphere.

When we analyse the data in 2 second fragments from the beginning, we see that Left hemispheric activity quickly becomes more prominent, Right

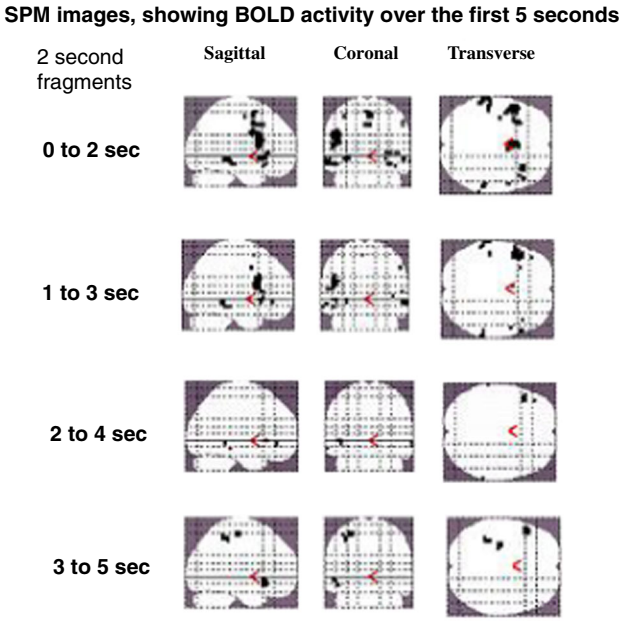

Fig. 3. SPM images, showing BOLD activity over the first 5 seconds

hemispheric much less so, until by the 5th second, only Left activity raises above FWE or FDR thresholds (see Figure 3).

Also note that medial prefrontal (SMA and Dorsal Cingulum) activity within *each* hemisphere, while strongest in the first 2 seconds, begins to fade relative to Dorsolateral Prefrontal activity.

The low temporal resolution of the BOLD fMRI response (some 2 seconds) does not allow us to make more detailed inferences about the very first 2 seconds, and we await the results of a Dynamic Functional Modeling analysis based on QEEG results (with their finer temporal resolution).

However, even within these limitations, we can say that the sequential patterns seen above suggest that in the initial 3 seconds, 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 to 2 with 1 to 3 and 2 to 4).

As times goes on however, negotiation ***between*** Left and Right hemisphere results in left hemispheric hegemony (compare the first 'transverse section' with the subsequent ones, and note how activity shifts to the Left hemisphere, and diminishes in the Right one). What are we to make of this dynamic pattern? We offer some points of orientation.

The 'resonance circuits'

The term 'resonance circuits' is used by Dan Siegel and his colleagues at UCLA (Siegel 2007, see especially Appendix III) to refer to the brain circuitry subserving ***mindfulness*** (our self awareness), and ***empathy*** (our awareness of others). The pathways begin at various mirror neurone sites in the lateral cortex, and project to the insula, which registers emotional self- and other-awareness through its subcortical limbic and hind brain conections, receives feed-back, and talks back to the middle pre-frontal region (mesial SMA and cingulate gyrus). The mesial cortex and cingulate gyrus have a well-described 'conflict monitoring' function. But the Dorsal Cingulum also seems to mediate aspects of self awareness. Thus the cingulate circuitry involves reflections (at various levels of conscious awareness) on differences between self and other. There is accumulating research evidence to support the validity of this mirror neurone/insula/subcortical/middle pre-frontal system as a substrate for relational awareness.

The Netherlands brain imaging neuropsychologist Christian Keysers (Keysers 2011) has recently published a detailed overview of the role of mirror neurone sites, the insula, and mesial cortex in empathy and self-awareness, and includes accounts of their early neurodevelopmental processes. Keysers and his colleagues use a slightly different terminology, the term 'shared' circuitry, to describe the processes that are referred to as 'resonance circuit' functions by Seigel and his colleagues.

We have overviewed the fMRI literature of the last 20 years to see what response patterns most closely match the pattern in our findings, and the 'resonance circuitry' is the one that corresponds most strongly (details of the literature review can be found in our Petchkovsky et al 2011 publication).

We see very strong activation of peri-Broca's SMA and Superior Temporal Mirror Neurone sites, anterior insula, cingulate gyrus, and parietal lobule (Fogassi et al 2005; Rizolatti & Craighero 2004). All of these areas survive FWE and FDR (Family Wise Error and False Discovery Rate) group analysis thresholds in our findings (or FDR alone for the parietal one, appearing in the 4th second).

While Siegel and his colleagues talk of the 'resonance circuits' primarily in the context of the relationship between the individual and his significant others, in the complexed response the process is a highly internalized one. 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 neurone activity is actually embedded in the observer's circuitry. And this accounts for occasional failures of empathy. Sometimes our mirror neurone activities do not match the actual internal experiences of the observed other. We can also make a distinction between representations of the internal other that are triggered by an actual external other, and those that are already embedded in the brain in memory, which

can be implicit/procedural rather than explicit/biographical/narrational (not readily accessible to ordinary introspection, which relies so much on words). Much of the implicit patterning, as we explained earlier, is laid down in the first two (pre-verbal) years of life, as object relations patternings, attachment styles, 'programmes' that the baby 'downloads' into their right hemisphere from their nurturer's right hemisphere, as Schore would put it (Schore 2003). This seems to be where the affect component that binds complexed response comes from. And even though the WAT is verbal, the affective circuitry that drives and binds complexed reactions is non-verbal.

Whereas left hemispheric development begins around the 3rd year, primordial 'self versus other' awareness begins much earlier in the human infant, as interactions with its caregivers impact on the development of right hemispheric and limbic circuitry, to lay down implicit memory patterns which shape perceptions to do with fear or safe protectors. This is discussed in detail by Siegel (Siegel 2007) and Schore (Schore 2003) and leads us to consideration of the separate roles of each hemisphere.

Left and right brain

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, worked with, and hopefully come to a 'transcendent function' resolution).

Let us explain. Much has been written about left versus right hemispheric function. Australian vision neuroscientist, Jack Pettigrew, was one of the first researchers in this area, and became particularly interested in the role of hemispheric switching in Bipolar Disorder, finding that Left hemispheric activity is higher in mania, whereas the Right hemisphere predominates in depression (Pettigrew 2001).

Perhaps the deepest and most comprehensive contemporary review of hemispheric functional differences is that of Iain McGilchrist (2010). In essence, McGilchrist argues that each hemisphere has its own distinctive mode of awareness or consciousness. The right hemisphere develops first (the first 2 to 3 years of life) and processes incoming data (including proprioceptive 'body field') holistically and emotionally. It mediates highly affect-loaded attachment and threat patterns. Right hemispheric over-activity in vertebrates is associated with wariness and depression (the subject as prey). Left hemisphere circuitry develops later, and processes in a linear rather than gestalt fashion, organized around language, logic and abstractions. At the affective level, left hemisphere is more curious, exploratory, danger-denying, even hypomanic (the subject as

predator). McGilchrist associates optimal mind-states with good interhemispheric communication because a third more integrative mode of awareness becomes possible. We wonder if much of Jung's biographic account of his Personality number One and Personality number Two reflected left versus right hemisphere function, and if Jung's intuitive genius rested on a particularly successful tango between his hemispheres.

A provisional model

Let us now bring these background understandings to bear in describing and interpreting our findings. The WAT depends on ***words***, a left hemispheric function. The stimulus word is received in the primary visual cortex and understood in the left upper temporal area (Wernicke's area of receptive speech). At this ***very early*** stage (the first 300 milliseconds), there will be no difference between neutral and complexes responses. (Thus they cancel themselves out when 'complexed' is contrasted with 'neutral'). However, the left amygdalar nucleus becomes activated if the generated associations are problematic. This amygdalar activation can be seen in the first 2 seconds in our scans, but does not achieve large statistical prominence probably because being very early and brief, it is drowned out by the activity of the much longer responses in the 'resonance circuit' sites.

The left word-finding (middle temporal) and word-generating areas (Broca's) now become vigorously activated as the subject struggles to find a suitable verbal response. By this stage, the 'resonance circuits' are operating vigorously. Within each hemisphere, conflictual word associative activity (middle temporal and Broca's) activate the mirror neurone sites near them (awareness of internal other), which in turn activate the insula, a site of somatic self-awareness. The insula in turn serves as a connective node between lateral cortical (peri-Broca's) and medial cortical (cingulate gyrus) activity, and the limbic system and hindbrain. The mesial SMA, a supra-ordinate mirror neurone site, is also involved. The cingulate gyrus, especially the middle part, is a well-known 'conflict monitor' and registers the tensions between experience of internal self and internal other. Thus there is a range of 'self' versus 'other' comparative processes going on at various levels ***within*** each hemisphere. And it seems that in each hemisphere, the lateral cortical circuitry to do with representation of the 'other' wins over the medial (cingulate) circuitry.

At a higher level still, the pattern of symmetrical activation suggests that the hemispheres are talking with each other, at least initially, and we surmise that the word-processing left hemisphere 'conveys its concerns' to the right hemisphere very early on in the piece.

The poor temporal resolution of the fMRI data for the first 2 seconds of the response makes it difficult for us to sequence the very early events. We suspect that the left (verbal) hemisphere activates first, but the right hemisphere is not

totally devoid of verbal ability. It's very good at prosody, but may also have picked some basic vocabulary from its more verbal sibling. We also know that the left hemisphere is more exploratory. The right hemisphere probably carries more of the fearful response (see our discussion of McGilchrist's work above). But within 3 to 5 seconds, the left hemisphere has 'won' the dialogue (see Figure 3, the first 5 seconds).

Implications for psychotherapy

Mindfulness and empathy

Much good psychotherapy involves establishing new patterns of relatedness especially in the domain of 'implicit relational knowing' (BCPSG 1998). The complexed response activates circuits relevant to such processes, the 'resonance circuits' that mediate mindfulness (awareness of self-concept and self-process) and empathy (awareness of the other, including the internal other in this case).

To resolve or tolerate the tension of internal conflict?

But our fMRI findings also show that the complex 'pseudo-resolves' the conflict through left brain dominance. But within the 'problem' of the complex, there is also a therapeutic opportunity (bringing awareness and compassion to work with the tension of opposites). As we know from clinical practice, the complex may continue to 'pseudo-resolve' the tension in this fashion forever, unless the 'holding of the tension of opposites' that Jung recommended can be done in a nurturant environment of safety, courage, and kindness, leading to the emergence of a 'transcendent function' mediatory product beyond the terms of the original conflict. It is worth remembering that as far back as 1977, Rossi 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' (Rossi 1977, p. 45).

Not all conflicts can be reduced to left vs. right brain, and our findings also show that ***within each*** hemisphere, the patterns associated with negotiations between internal self and internal other can be seen in the first 3 or so seconds. But the interhemispheric dialogue is also quite striking.

Organizational brain lock

Left brain hegemony can be institutional. Within psychoanalysis, the rigid disdain that met Winnicott and Bowlby's focus on early nurturance and developmental process is a good example. Sebern Fisher, a US therapist who specializes in the treatment of Reactive Attachment Disorders, gives a particularly good account from outside the psychoanalytic profession of the institutional

acrimony that met Winnicott and Bowlby (Fisher 2009, pp. 317–18). Another example might be the prescriptive rigidity of the psychoanalytic couch (or the Jungian two chairs for that matter). But more importantly, locked left brain self-righteousness, or the inconsolableness of rampant right brain process, usually point to inherent problems, whether in the individual or the group.

The relationship between archetypes and complexes

We were interested to find whether these fMRI results would tell us anything about the 'transcendent' axis of Jungian psychology, facing forward towards teleology and individuation, and backwards towards the archetypes and the collective unconscious. However, the results do not point us in any particular direction and further research would be required to indicate how complexes are influenced by archetypal factors (factors beyond biographic environmental ones). Gyorgi Buszjaki, a leading neuroscientist who through his work with EEG wave forms became interested in the role of oscillations in brain function, from the physics of oscillations through to its role in neuronal assembly organizational through to complex cognitive processes (Buszjaki 2006). There is a connection between this and Jung's formulation of 'the play of opposites' in the psyche which deserves further investigation. We commend the way Buszjaki's 'emergent' neurobiology can account for the generation of complex brain states without the intervention of a divine microarchitect and, similarly, we strongly support an 'emergent' understanding of complex and archetypal theory, as outlined by Roesler (2012), Knox (2011) and Merchant (2006, 2009). Emergence is sufficient. Nevertheless, it is by no means clear that all complex contents (as opposed to structures) *must* be biographically generated. There seems to be a peculiar 'openness' in many children from the age of 2 to 4 or so, who will give accounts of matters that cannot be easily reduced to biographic factors, cryptomnesia, or imaginative construction. Jung was aware of this, especially in the dreams of very young children (see Jung 1976, p. 51) and the accounts of so-called 're-incarnation' imagery in young children detailed by the Canadian psychiatrist Stevenson also come to mind (Stevenson 1974).

Some of the authors have also noted spontaneous productions of similar material from their children, grandchildren, and the children of some of their patients. Clearly, studies need to be done of 'paranormal' experiences in infancy /childhood.

Directions for further research

- **Repeat studies.** The present study fits in the Pilot category. Though the findings are robust, replication is needed, preferably with Galvanic Skin Response (GSR) and Heart and Breathing rate facilities (Polygraphy).

We were hoping to include these in our study, but the technician who was going to install the technology resigned before this could be done. GSR and Polygraphy responses provide additional means to identify complexed responses even more accurately and objectively, which is why Jung used this in his original studies. Greater numbers of trials will also allow us to make a clearer distinction between conscious and unconscious complexed responses, and perhaps even begin to differentiate between different 'types' of complexes.

- **Microdynamics**. QEEG studies (with their finer time resolution) are needed, for comparison/contrast with fMRI, but also to discriminate the microdynamics within the first 2 seconds. This can be done by bringing an Independent Component Analysis to the responses. We suspect that ERP (Evoked Responses Potential) changes, especially in the P300 range (activities emerging around 300 milliseconds) will be a feature of the complexed response, because these are often seen in association with cingulate gyrus dysfunction.
- **Comparison with other conditions**

  - Eliciting the dynamics of the complexed response in a range of diagnostic categories is also vital; we have schizophrenia especially in mind, since clinically, as Jung noted, it seems as if in schizophrenia, the complex tends to overwhelm the ego. We have noted, in our very preliminary work with EEG responses to the WAT, that patients with schizophrenia tend to have much more prolonged complexed responses. Some of them even experience an outburst of auditory hallucinations.
  - Brain functional imaging studies of WAT responses in persons with disorder of self organization (like borderline conditions and attachment disorders) will throw more light on the neurodevelopmental processes in such disorders.
  - The WAT is only one paradigm for eliciting complexed responses. Various pre-verbal stimuli (visual, haptic/gestural, olfactory) can generate painful responses. Such protocols could enable us to observe these processes in infants and babies. The Yale child psychiatrist Kevin Pelphrey has developed baby-friendly fMRI procedures (Pelphrey 2012).
  - Complexes in PTSD are also worth studying. It may settle the issue of whether *all* complexes are forms of PTSD or not.

The psychology/neuroscience tango

Jung's initial combined engagement with empirical/scientific and introspective/subjective approaches proved highly innovative. The development of powerful brain imaging technologies allows us once again to engage in this creative dance.

Good depth psychotherapy increases our capacity for the detailed mental examination of our feelings, thoughts, and motives (and those of others). This

allows us to bring more refined research questions to the neurosciences domain. In turn, recent advances in neuroscience let us bring an ever more powerful lens to processes of subjectivity.

Translations of Abstract

Le Test d'Association de Mots de Jung s'est déroulé dans les conditions du fMRI avec 12 sujets normaux. L'ensemble des réponses altérées a été comparé à un ensemble de réponses neutres. Le modèle d'activation fMRI de cette « réponse altérée » moyenne était très fort (scores Z corrigés allant de 4.90 à 5.69). Le modèle d'activation dans chaque hémisphère inclut des zones de neurones en miroir qui repèrent « l'altérité » (empathie de perception), la partie antérieure de l'insula (à la fois conscience de soi et empathie émotionnelle), le gyrus cingulaire (conscience de soi et contrôle du conflit). Ce sont les localisations décrites par Siegel et ses collègues comme le « circuit de résonance » dans le cerveau qui est essentiel pour l'attention (conscience de soi) et l'empathie (sens de l'autre), et les négociations entre la conscience de soi et « l'autre interne». Mais il y aussi un dialogue interhémisphérique. En moins de 3 secondes, l'hémisphère gauche l'emporte sur le droit (au moins chez nos sujets normaux). L'attention et l'empathie sont essentiels pour une bonne psychothérapie, et les complexes peuvent être des ouvertures possibles si l'hégémonie du cerveau gauche est contenue. Cette étude pose les bases de recherches ultérieures : (i) études des réponses complexes sur l'EEG (avec la résolution temporale la meilleure) chez les sujets normaux ; (ii) EEG et études fMRI des réponses complexes dans d'autres conditions, comme la schizophrénie, PTSD, troubles de l'organisation de soi.

Jungs Wort-Assoziationstest wurde unter fMRT-Bedingungen mit 12 normalen Probanden durchgeführt. Aggregierte komplexe Antworten wurden mit aggregierten neutralen kontrastiert. Das fMRT-Aktivationsmuster dieser generischen 'Komplexantwort' war sehr stark (korrigierte Z-Werte zwischen 4.90 und 5.69). Das Aktivationsmuster in jeder Hirnhemisphäre schließt die Gebiete der Spiegelneuronen, die 'Anderssein' (perspektivisch Empathie) beinhalten, den Cortex insularis (sowohl Selbstwahrnehmung als auch emotionale Empathie) und den Gyrus cinguli (Selbstwahrnehmung und Konfliktverarbeitung) ein. Dieses sind die Orte, welche von Siegel und seinen Kollegen als das 'Resonanzschaltzentrum' des Gehirns beschrieben werden das für die *Achtsamkeit* (Gewahrwerden des Selbst) und die *Empathie* (Sinn für den Anderen), den Austausch zwischen Selbstwahrnehmung und dem 'inneren Anderen' von zentraler Bedeutung ist. Aber es gibt auch einen Dialog zwischen den Hemisphären. Innerhalb von drei Sekunden setzt die linke Hemisphäre die rechte außer Kraft (wenigstens bei normalen Individuen). Achtsamkeit und Empathie sind wesentlich in einer guten Psychotherapie und Komplexe können Fenster für Chancen sein wenn der Vorherrschaft der linken Hirnhälfte widerstanden wird. Diese Studie legt Grundsteine für weitere Forschungen: (1.) QEEG-Untersuchungen (mit ihrer feineren temporalen Auflösung) bezüglich Komplexantworten bei normalen Probanden, (2.) QEEG- und fMRT-Studien zu Komplexantworten unter anderen Bedingungen wie Schizophrenie, PTBS, Störungen der Organisation des Selbst.

Il Test Associativo Verbale di Jung venne eseguito da 12 soggetti normali sotto le condizioni fMRI. Una serie di risposte complesse vennero messe a confronto con una serie di risposte neutrali. Lo schema di attivazione del fMRI di queste generiche 'risposte complesse' fu molto forte (corretti Z punteggi che andavano da 4.90 a 5.69). Il pattern di attivazione in ciascun emisfero include l'area dei neuroni specchio che tracciano 'l'alterità' (empatia prospettiva), l'insula anteriore (sia la consapevolezza di sé che l'empatia emotiva), e la circonvoluzione cerebrale (consapevolezza di sé e monitoraggio del conflitto). Queste sono le aree descritte da Siegel e colleghi come 'i circuiti di risonanza' nel cervello che è centrale alla *attenzione* (consapevolezza di sé) e alla *empatia* (senso dell'altro), le negoziazioni fra la consapevolezza di sé e 'l'altro interno'. Ma vi è anche un dialogo intraemisferico. Entro 30 secondi l'emisfero di sinistra passa oltre quello di destra (almeno nei nostri soggetti normali). L'attenzione e l'empatia sono centrali per una buona psicoterapia e i complessi possono essere finestre di opportunità se l'egemonia del cervello sinistro resiste. Questo studio getta le basi per ulteriori ricerche: (i) gli studi QEEG di risposte complesse in soggetti normali (con la loro più sottile risoluzione temporale); (ii) gli studi QEEG e fMRI di risposte complesse in altre condizioni, come nella schizofrenia, nel PTSD e nei disordini di organizzazione del sé.

Тест Юнга на словесные ассоциации проделывался в условиях ФМРТ с 12 нормальными субъектами. Объединенные ответы, указывающие на комплексы, сравнивались с объединенными нейтральными ответами. Паттерн активации ФМРТ такого обобщенного «комплекс-ответа» был очень сильным (откорректированные Z баллы в шкале от 4.90 до 5.69). Активация паттерна в каждом полушарии включает области зеркальных нейронов, которые отслеживают «инаковость» (проективная эмпатия), переднюю долю (самосознание и эмоциональная эмпатия) и поясную (цингулярную) извилину (самосознание и мониторинг конфликтов). Это области, описанные Сигелем и коллегами как «резонансная схема» мозга, центральные для формирования осмысленности (осознания себя) и эмпатии (чувствования другого), обменов между самосознанием и «внутренним другим». Но существует также и межполушарный диалог. В течение 3 секунд левое полушарие доминирует над правым (по крайней мере, у наших нормальных субъектов). Осмысленность и эмпатия являются центром хорошей психотерапии, а комплексы могут стать окнами возможности в тех случаях, когда есть сопротивление гегемонии левого полушария. Это исследование закладывает основы для будущих: 1)для исследования способом количественной электроэнцефалографии (с ее более тонкими временными разрешениями) комплекс-ответов нормальных субъектов; 2) для КЭЭГ и ФМРТ исследований комплекс-ответов в иных условиях, например, при шизофрении, пстр, расстройствах самоорганизации.

El Test de Asociación de Palabras de Jung fue realizado bajo condiciones de fMRI por 12 sujetos normales. Las respuestas complejas de fueron contrastadas con las neutras. La pauta de la activación de fMRI de esta 'respuesta genérica compleja' fue muy fuerte

(corrigió cuentas Z que recorren de 4,90 a 5,69). El patrón de la activación en cada hemisferio incluye áreas de neurona en espejo que rastrean la 'alteridad' (empatía de perspectival), la Insula anterior (tanto la conciencia de sí mismo como empatía emocional), y Gyrus Cingulado (la conciencia de sí mismo y vigilancia de conflicto). Estos son los sitios descritos por Siegel y colegas como la red de 'circuitos de resonancia' en el cerebro que es central al *totalidad mental* (el conocimiento de ser) y la *empatía* (sentido del otro), las negociaciones entre auto conocimiento y el ' otro interior '. Pero hay también un diálogo de interhemisférico. Dentro del lapso de 3 segundos, el hemisferio izquierdo sobrepasa al derecho (por lo menos en nuestros sujetos normales). La totalidad mental y la empatía son centrales para una buena psicoterapia, y los complejos pueden ser oportunidades si se resiste a la hegemonía de hemisferio izquierdo. Este estudio sienta las bases para la investigación adicional: (i) Estudios de QEEG (con su resolución temporal más fina) sobre respuestas complejas en sujetos normales; (ii) QEEG y estudios de fMRI de respuestas cpmplejas en otras condiciones, como la esquizofrenia, PTSD, los desórdenes de auto organización.

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