

Mirror Neurons and Premotor cortex leakage

A review, particularly focussing on implications for therapeutic protocols and the practical use of the body

Final version 5.0 :: April 2015

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Preamble

The mirror is one of the strangest and most magical of human inventions. We look out at the external world, and see ourselves staring back. Mirrors are so ubiquitous that – for most people - it is difficult to imagine a house without several – one in the bathroom, one in the bedroom, maybe others dotted round various rooms. We wash ourselves and shave and brush our teeth under our own gaze. At one time I was so taken at how much the mirror image of myself seemed to dominate my sense of self and identity that I totally stopped using mirrors for a couple of years. It took several months to drop into a more body-centred sense of who I was. Little by little, the quasi-visual externalised image faded and the physically experienced *embodied* sense of self strengthened.

In the beginning, in the soup of life, who knows how the smallest of lifeforms detected the state of their environment. I once read a booklet by Steiner on taxonomy¹, in which he described the various functions and relationships of different classes of life. His description of fish (a subset of *cordata*, the bony midline-symmetric beasties that include humans) was particularly poetic. He talked about the fish being unaware of the distinction between the fluids inside its body and the sea that it swam in – so they swim, motes in their own infinity of existence, moving within the entire hydrologic cycle – maybe within the tide of life itself.

Humankind (and possibly all self-reflective/self-aware air breathing animals including corvids, parrots, cetaceans, elephants) lives within its own sea – we breathe in and out. There are spiritual traditions that talk of the breath as being a connection to the infinite. We draw in the air, bringing the infinity of space into our bodies, as our ribs expand out like the mantle of a jellyfish – we expand into the diffuse realms of the space that surrounds our bodies. Then we breathe out – becoming small again, coming down to Earth, embodying, condensing, solidifying. This *breath in, breath out, breath in, breath out* is a living symbol of the polarity that defines our place in the cosmos, a lightning rod held in suspension between spirit and matter. And within that sea we require some means of navigation – a sense of magnetic flux, the position of stars, the scent of a forest of kelp – all these and more are symbols and signs between staging posts, moments, lifetimes. This may sound rather plump with poetic licence. But as you will see, the way that mirror

¹ Steiner, Rudolf Trans: R. Stebbing (8 lectures, Berlin May-Jul 1917, GA176) Aspects of Human Evolution. 186pp; ISBN 9780880102520

neurons blur the distinction between external and internal worlds, we appear to be hard wired to experience the world more like Steiner's fish than the objective rational beings that we think we are.

Within all this flux, it is the sensory system that connects us to the here and now that our bodies are taking part in. The senses may be categorised into two (somewhat overlapping) branches. The internal senses provide information about our internal environment, including proprioception (where limbs are, what position the body is in). And external senses look “out there” at the environment we live in. The externally oriented sensory system has only one purpose – to obtain information about our environment so that we can act within it and react to it. Thus, external senses are useless without some kind of interpretative relay that results in at least the possibility of an appropriate *movement*-response via the musculoskeletal system. The senses are useless without the ability to both interpret and apply the information they provide ... and the interpretation is apparently impossible without some prior experience of both sensing *something* and applying that movement. This is not only an evolutionary paradox but also a developmental one. Particularly in the case of living organisms that do not possess the same level of developed central nervous system (CNS). It suggests, implicitly, that this kind of learning occurs well below the cortical level. And that evolutionary processes are not only Mendelian, but also include a large element of intelligent (i.e. Lamarckian) adaptation.

Similarly the internal senses tell us about our internal state – and most of the options for useful response to that information involve some form of movement and/or orientation relative to external senses. Or they tell us what is happening with our movements and help us to control and adapt them. Sometimes a “movement-response” is a *no*-movement (stillness, freeze, or drawing subtly inwards – three variations occupying three very different places on the physiological spectrum). But nevertheless, even the deliberate absence of movement takes place as a result of sense followed by interpretation. We may sense nothing of any particular usefulness or threat, in which case, if we don't need to eat right at this moment, the non-movement might be a relaxed one. Or it might be a freeze where our attention is placed more strongly on the senses and we make ourselves less visible by – not moving.

The hard wiring in the brain that connects our nervous system to this sensorimotor relationship between inside-outside are in the premotor cortex, and *mirror neurons*² are particularly important in this regard.

2 http://en.wikipedia.org/wiki/Mirror_neuron

How mirror neurons work

In essence, with lots of not so superfluous detail temporarily skated over, mirror neurons

- **play out the (external) actions that we observe other people making *as if we were doing them ourselves*.**
- **play out what we are imagining ourselves doing “as if” we are moving, without the need to actually carry out that movement.**
- **interpret sensory information, motor usage, and even ideas - into a motor-based symbolic “language” that is understood by primitive non-verbal parts of our being/organism – i.e. deep within our physiological processes.**

The original discovery of mirror neurons³ came about at the University of Parma, Italy. As part of a study of the ventral premotor cortex of the macaque monkey, researchers accidentally found that the same neurons fired in the monkey when it was watching a researcher – as when it was performing the same task itself. The original submission of this remarkable finding to Nature was “*rejected for its lack of general interest*”.

Many of the aspects of awareness and other mental processes are based on biological requirements for survival, adaptation and the necessary level of responsiveness to the external environment. As such they are mediated and controlled in quite primitive parts of the nervous system – parts that have been around since we were maybe earthworms or sea squirts or jellyfish. The primary survival interest of our body/being is in determining **meaning** - in quite a limited sense of the word. The most important aspect of *meaning* is the relationship between ourselves and the perceived environment. One way that a sense of meaning and relationship comes about is through the action of mirror neurons. Put in a simple way – these play out external scenes, noises, maybe even scents and tastes, *as if they were happening internally*. Mirror neurons take everything personally.

On the most basic level, biological meaning is most interested in the polarity between positive survival (food, shelter, reproduction, territory) and danger (i.e. mortal threat). So everything we sense is passed by two different parts of the brain – the amygdala (which handles memories of danger/fear/threat) and the anterior cingulate gyrus (which handles pleasant/reward memories). It appears that the decision making process between these two is almost purely based on the volume of “noise” that each produces, with the decision to act in any particular way being based on which is firing most strongly⁴. This summation of the balance of threat or pleasure is relayed to the conscious mind (and to the animal body) via emotions, urges, feelings, movements. The premotor cortex mediates all this activity, both presenting these two brain regions with symbolic information and preparing the movements that are generated as a response.

3 Rizzolatti, G & Craighero, L (2004) The Mirror-Neuron System. Annual Review of Neuroscience 27:169-92
doi:10.1146/annurev.neuro.27.070203.144230

4 There are other options – if you are at all familiar with Buddhist practice you may already have noticed the classic polarity of “craving and aversion” in the above statement. However, at this point we are discussing primitive survival reflexes – and Buddhist meditation practice demands that we step outside our primitive self and into our adult conscious observer self.

For instance – if somebody who I am looking at is smiling, my mirror neurons would be firing as if they were activating *exactly* the same facial muscles in *my face* – and so I would sense internally if the smile were genuine because my body would say something like “when I move my face muscles like that, I feel happy/ gracious / loving / deceitful / embarrassed / uncertain / half-heartedly welcoming” - or whatever. If the quality of information being passed to mirror neurons is high enough, we become capable of detecting fake smiles from real ones – by almost imperceptible changes in the perceived muscle usage. If you reflect a little about how easily you do this in your everyday life, and how often this innate skill is used, you will realise that it is a major component in most communication. Milton Erickson, the father of modern clinical hypnotherapy, stated that information passed through verbal communication is processed as roughly 7% words, 38% intonation (tone of voice) and 55% body language (including, but not necessarily restricted to facial expression).

In certain circumstances this *internal* mirroring can spill out into an external mirroring movement or posture – a direct copy of what is happening in front of us. A common event in congruent and genuine 2-way conversation is that people adopt the same facial expressions and body language. This is called (from a biological and anthropological point of view) - *mimicking*, and is a natural response with many uses. It occurs when the (externally interpretative) mirror neuron states are allowed to pass (leak) from the premotor cortex into the motor areas of the brain.

For people who are capable of exercising a good control over the mind-body link, it is possible to more or less choose whether the premotor cortex leaks out into the motor cortex – or not. However, very few people are capable of exercising so much control that they can completely censor this leakage. And even for those people – as we shall see later – the lack of leakage is accompanied by a reduced movement (“freeze”) in the muscles that are being prepared to respond. For some people, the leakage is uncensored and uncontrolled, and these *psychotic* states were described by Pierre Janet⁵.

Figure 1 :

Pierre Janet
– photo from
WikiCommons



<http://en.wikipedia.org/wiki/File:PierreJanet.jpg>

Leakage can also be cultivated to occur “on demand” such that spontaneous movement occurs in a useful way.

So mirror neurons are particularly important in social communication – particularly those aspects

⁵ <http://www.trauma-pages.com/a/vdhart-89.php>

of communication that require some level of empathy⁶. In fact, we know this already without even needing to know of the existence of mirror neurons. When we talk of empathy and sympathy, the experience being described includes some element of taking on the emotions felt by the other person, and mirroring/expressing them back to that person in an appropriate manner and context. This empathic communication occurs because we have learned that partial and controlled leakage of the premotor mirroring cortex is a useful trait in some social situations. Most of this decision making is on the borderline between conscious and unconscious, with (again) some people being far more adept at being aware of this grey area of consciousness and so more capable of exercising conscious control over the type of leakage that occurs. So high quality communication skills require a significant level of presence and mindfulness or “now”-awareness. And this system is so sensitive that if we are disingenuous in our mirroring, the other person will detect this and (if they are self-aware) feel unease. The more skilled the faked body language, the less easy the unease will be to identify or verbalise, but nevertheless, it will still be there.

The premotor-motor hall of mirrors

A piece of research published in 2014⁷ shows how the motor and premotor cortices arrange themselves. Until I read this paper, I assumed that the motor cortex simply does not fire at all in response to premotor activity until it is told to do so. In that case it would have been analogous to a layer of soundproofing that is capable of converting itself into a sound transmitter. i.e. The signals in the premotor cortex would simply not be passed on. In fact, activity anywhere in the brain has an effect regardless of where it is passed to – simply because more neurons are firing and the electromagnetic implications of that increased activity. The brain – or at least the motor area of the brain - cannot just seal itself off from the body to inhibit movements it is preparing and contextualising. So – what really happens is that – *when the premotor cortex fires up, the motor cortex reduces its background activity to balance the premotor signal, with the total “noise” of activity in that sector of the brain (i.e. the motor cortex plus its associated premotor area) remaining the same.* This is very much analogous to an active noise control (ANC)⁸ device works. A sound is neutralised (using headphones) by producing an “anti-sound”. In the case of ANC, the anti-sound is a signal equal to the noise but phase shifted exactly half a wavelength. In the case of the brain, the motor cortex produces a negative “image” of the activity in the premotor cortex (almost like a photograph that has been colour inverted) by inhibiting motion in the related body parts. Thus the brain is constantly flipping between action/movement and inhibition⁹.

What gets really interesting is when we are acting/moving and also processing external information (sights, sounds, maybe words) that have a different symbolic meaning from the

6 Marco Iacoboni (2008) The Mirror Neuron Revolution : Explaining what makes humans social. Scientific American July 1 , 2008 (17)

7 Matthew T Kaufman, Mark M Churchland, Stephen I Ryu, Krishna V Shenoy. Cortical activity in the null space: permitting preparation without movement. Nature Neuroscience, 2014; DOI: 10.1038/nn.3643, summarised in <http://www.sciencedaily.com/releases/2014/02/140202132337.htm>

8 http://en.wikipedia.org/wiki/Active_noise_control

9 Stanley Keleman is more or less definitive on the biological origins and development of inhibition in body psychotherapy. e.g. see Keleman, S (1989) Emotional Anatomy ISBN 0934320101 and Keleman, S (1987) Embodying Experience: Forming a Personal Life. ISBN 0934320128

movements we are making. For this to happen, there must be a capacity to parallel process – inhibiting the symbolic representation whilst still performing the externalised movement. Some people have a substantially reduced capacity to do this, and others have obviously high levels of parallel processing capacity – we say they are good at multitasking.

We have already heard that the motor cortex (MC) inhibits activity of the cortical segment to balance out the activity in the pre-motor cortex (PMC) until that activity is ready to be expressed. The implications of this behaviour of the PMC and MC as complementary and interacting centres of preparation and expression – are substantial, and fit well with the phenomenology of movement-expression.

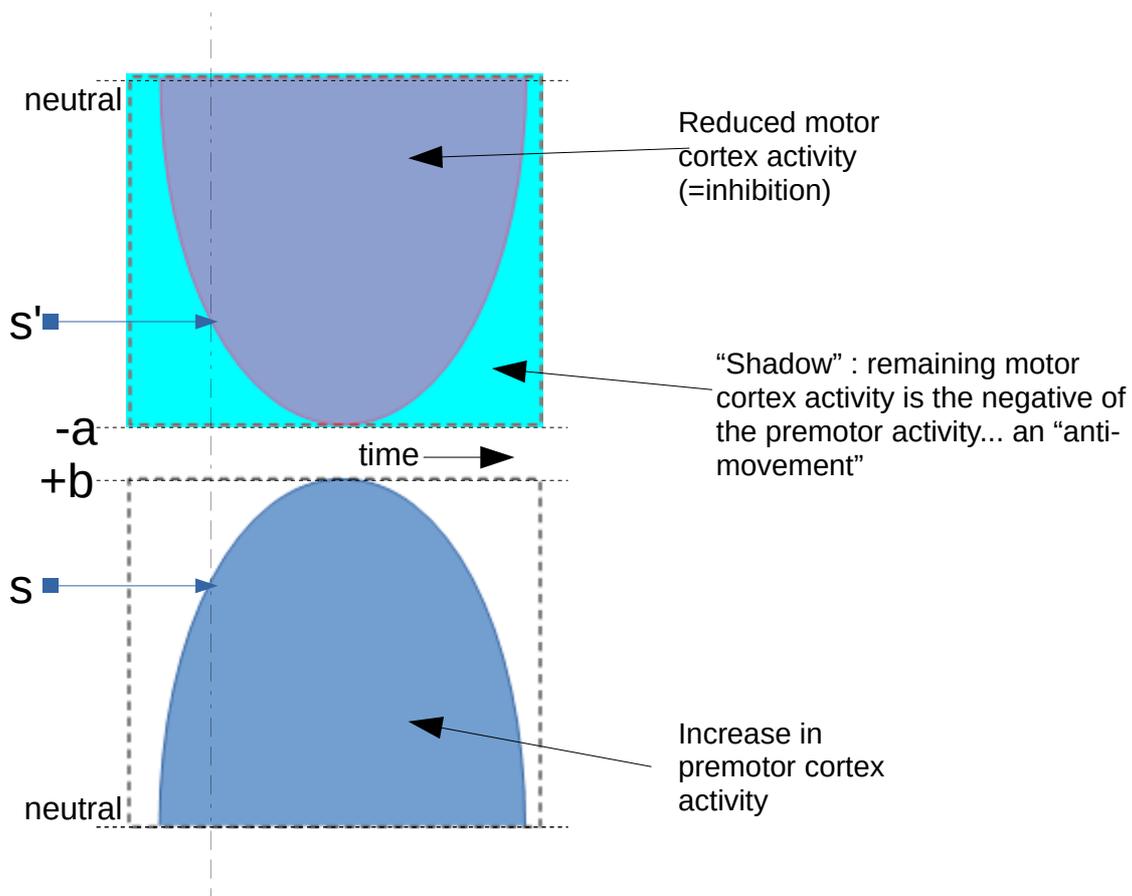


Figure 2 :
A representation of the relationship between Motor and PreMotor cortical activity for an unexpressed action held in the PreMotor layer.

Total activity in this segment of the cortex $s_{tot} = s+s'$ ideally remains unchanged. This takes place when the increase in premotor activity (+b) is exactly matched by the decrease in motor activity (-a) : i.e. $a=b$. If $a<b$, then the inhibition is not sufficient, and the premotor activity starts to increase total activity in the cortical segment, with a resultant expression of the premotor contents.

The MC sits laterally between the parietal and frontal areas, and the PMC lies between the MC and the prefrontal lobes. ***For any specific activity in the PMC that is not ready to be immediately expressed now, the MC reduces its activity to equally balance the***

increased activity of the PMC, such that the affected segments of the total P/MC exhibit no change in total activity. For this to be possible at all, there must already be a “froth” of activity in the MC so that a decrease is possible... In practice, the synaptic control of movement is a FM (frequency modulated) system rather than AM (amplitude modulated), so as more synapses fire in the PMC (or the same synapses fire more frequently), there is less firing in the MC. The froth of “neutral” cortical activity can be thought of as some level of background synapse activity that checks the state of the body via afferent nerve fibers, and that maintains some synchronisation between the CNS and local oscillations (essential tremor). – i.e. the motion is preceded by a period of relative reduction in synchronisation/control between the MC and the muscles that are being prepared to fire. In this preparatory “pause”, the locally generated (as opposed to centrally controlled) essential tremor of each muscle fiber receives less signal from the CNS, and so may enter a state where it is no longer entrained to the MC. In contrast, the muscles not included in the prepared PMC activity remain synchronised/entrained (which is the “anti-movement” demonstrated in Figure 2). When the motion is allowed to express, the MC stops inhibiting and takes up the signal being presented to it by the PMC – and the PMC then prepares for the next motion.

How long is this preparatory stillness? Essential tremor¹⁰ takes place at about 10Hz (0.1 seconds), which is also approximately the frequency of alpha waves (and several other physiological processes in the body). The inhibitory action of the motor cortex has to be able to interrupt that tremor at 1/2 and 1/4 phase points, so that it can transform an oscillatory motion into a continuous smooth motion, Therefore this signal has to refresh at about ($4 \times 10 = 40$) 40Hz which, interestingly, is the EEG frequency range found in the midbrain.

The EEG itself is not really a literal frequency of activity, but rather is a summation of all synaptic activity in the brain. So a “frequency” of the EEG is representative of a ripple of stimulation – i.e. it records the wavelength of increases and decreases of activity passing through that part of the brain (something like a Brazilian wave!) – rather than literally being the frequency of the actual synaptic signalling. And the amplitude of the EEG is representative of the relative number of synapses firing at any one moment. If you consider the leaves of a tree or field of grass being blown in the wind, there will be a noise and movement that has a certain frequency, which is partly random as each individual stalk or leaf moves (individual neurons fire), partly a result of them being connected together mechanically (the stalks push each other, the leaves move according to the resonance of branches – groups of efferent neurons fire in a coordinated fashion), and partly resulting from eddies and turbulence in the wind (afferent signals impose their own pattern through the CNS). And what we “see” is a larger and much slower pattern of motion, which has the appearance of order. This order arising from (apparent) chaos is common in many areas of the natural world. The underlying micro-level chaos is not truly chaotic (as in being truly random), and so contains a seed of the more visible macro-pattern that is emergent.

In CST we also would also say that (perceptually) CNS activity either requires or induces (or both) changes in gross movement of neural tissue. One possible mechanism for this would be small changes in mechanical stiffness as blood flow changes, resulting in an altered local and regional mechanical response to (e.g.) the cardiac pulse.

¹⁰ <http://www.hummingbird-one.co.uk/pdf/Muscles.pdf>

Despite its complexity, the above description is in turn a simplification of rapidly changing MC/PMC activity and is not so straightforward in practice. On a more primitive level, the muscle fibers and groups are engaged in a locally (spinal nerve) generated essential tremor in which (ideally) agonist and antagonist are engaged in a controlled and almost imperceptible mutual vibration. If there is no immediately obvious ideal choice of response/reaction, then the duration of stillness/inhibition/ pause lengthens.

On a higher level, we are capable of multiple “tasks” and of being aware of multiple sensory inputs – Freud considered that we can be aware of up to four different sensory foci at once. Experience tells us that we can simultaneously

- i. think of one action,
- ii. perform another,
- iii. listen to a conversation,
- iv. speak or sing or think of words or recall a memory,
- v. feel sensory information from (e.g.) our fingertips, feel an emotion, and see/hear external colours, shapes and watch other people expressing different emotions and movements from the ones we are expressing/ experiencing.

All of these (i) through to (vi) are literally and/or symbolically processed by the PMC, and may involve many different body parts. In addition to this more or less conscious activity, the PMC also receives (or generates) a habitual response to all of the perceived internal and external environment.

Although the activities (i) through (iv) may be theoretically capable of being totally decoupled, I have not yet met anyone who can totally decouple one of them from all the rest – in that there is always a shadow of the other activities that subtly (or not so subtly) changes the expression of each. Since each of these will have in one way or another to affect the activity of the PMC (and therefore of the MC), there are interesting subsidiary questions as to how much parallel processing is possible in segments of the cortex, and how that might be achieved. The two most obvious technological analogues are multiplex signalling (where different messages are transmitted at different frequencies) and distributed processing (where a multiple task is divided between different processors – in this case somehow the synaptic activity compartmentalises so that some neuron groups are dealing with one task and other physically proximal groups are dealing with another task). Based on a few conversations about learning capacity¹¹, I suspect that both of these occur.

All the conscious and non-conscious material passing through the PMC – either literally preparing for movement or engaged in (mirror neuron) symbolic representation of the external world – therefore inevitably creates a frissant of activity at a physical level – either through increased stillness (in Figure X, this is $a = b$) or through leakage of the movement into the MC by insufficient inhibition ($a < b$). Thus, whatever we think, feel, remember, see, hear or say creates a progression

11 <http://www.humanbottleneck.com/index/ebook/>

of *micromovements* and *microstillnesses*¹² throughout the body. In cases of severely reduced inhibition these can become gross movements - which may be oscillatory (as in Parkinson's Disease), or more gestural - such as the movements of the inmates in the Paris sanatorium observed by Pierre Janet. The type of inhibition that has been lost is different in these two cases.

Considering the phenomenology of the “freeze”/ startle and “floppy”/submission reflexes, I would guess that the total activity of the MC/PMC increases as sympathetic tone increases, but that the MC still balances out the PMC until action is “allowed”. The freeze response in particular is characterised by a semi-rigid vibration/trembling where agonist and antagonist muscles are equally prepared and the amplitude of essential tremor perceptibly increases – the essential tremor has upped a notch, like a guitar string being moved by an increasingly strong breeze.

Interestingly, the temporary reduction in synchronisation between MC and soma when mirror neurons are engaged contains a possible mechanism for *both freeze* (i.e. a temporary immobilisation of the MC in the area that is gearing up for action – see figure 2) and for partial somatic **dissociation** (i.e. loss of CNS entrainment following a prolonged period of MC inhibition of the PMC).

Whenever I think about possible mechanisms behind these processes I always return to Dana Zohar's suggestion that consciousness is a Bose-Einstein condensate (BEC) within microtubules. Thus multiple states of coherence (and incoherence) can exist simultaneously – in different volumes of the body and also in overlapping or even mutual volumes of the body. If preparatory and modelling activity of the PMC temporarily reduces synchronisation between the MC and the soma, there must be some mechanism to re-instate that synchronisation. BEC activity is one possibility for how that works, and so loss of an integrated BEC field throughout the body means that the “clock” that ties MC and muscle fibres is also compromised – and that mechanism is what we call consciousness.

So far we are only describing non-conscious (reactive) processing. There is also a possibility to consciously observe our internal state and the external environment so that we *choose* how to respond. This involves yet more inhibition, through active use of the frontal lobes. It also requires a presence – a sufficient awareness of *now* so that the will has an effect on the body.

Looking at Taiji/Qigong movements in this light, they take place by the whole body being moved in synchrony – if a wrist moves, then that movement passes through the core and is supported by movement of all the other joints, no matter how small that supporting movement might be. Movements are spiral, so engage *all* of the muscles in a ripple, the activation of which is in a pattern similar to those already present in the cortex. They also engage the whole body in a movement pattern that is as close as possible to the primitive swimming motion inherent in early vertebrates (fish). There is also almost always a preparatory opposite movement that precedes the actual movement – which primes the agonist/antagonist muscle groups so as to achieve greatest efficiency of motion.

Taking an even less less mainstream view of the function of the brain, there is still a fundamental causal ambiguity if one takes into account the question of whether the brain is truly a master computer; or whether its function is much more as an information relay organ, with much of that

12 actually vibratory states where essential tremor is not inhibited

information traffic taking place on the high frequency end (3000-300,000 Hz) of the EMG spectrum. Are the MC and PMC truly “directing” motion, or are they merely a necessary information integration and relay station, with the motive “will” occurring elsewhere...? In fact, we have very little idea how or where the conscious act of will is generated and then passed through the organism, or how the distributed intelligence of the cellular body works as a unified whole – whilst still retaining enough loose coupling such that central control is actually more of a general instruction by a managing director to his intelligent employees rather than a series of specific instructions from a controller. Intelligence in the body is hierarchical. From this perspective, it could be that the MC and PMC are simply tuned to slightly different high EMG frequencies which they then express as synapse activity.

In CST we would also say that (perceptually) CNS activity either requires or induces (or both) changes in gross movement of neural tissue. One possible mechanism for this would be small changes in mechanical stiffness as blood flow changes, resulting in an altered local and regional mechanical response to (e.g.) the cardiac pulse¹³.

Despite its complexity, the above description is in turn a simplification of rapidly changing MC/PMC activity and is not so straightforward in practice. On a more primitive level, the muscle fibers and groups are engaged in a locally (spinal nerve) generated essential tremor in which (ideally) agonist and antagonist are engaged in a controlled and almost imperceptible mutual vibration. If there is no immediately obvious ideal choice of response/reaction, then the duration of stillness/inhibition/ pause lengthens.

13 Robert Hamilton, Kevin Baldwin, Jennifer Fuller, Paul Vespa, Xiao Hu, and Marvin Bergsneider (2012) Intracranial pressure pulse waveform correlates with aqueductal cerebrospinal fluid stroke volume. *J Appl Physiol* (1985). Nov 15, 2012; 113(10): 1560–1566. Published online Sep 20, 2012. doi: 10.1152/jappphysiol.00357.2012, PMID: PMC3524656

Learning by osmosis

Mirror neurons are particularly important in the early stages of infant development. Babies in particular (and toddlers to a slightly lesser degree) learn how to use their body by tuning into the adults around them. They learn how to use and interpret emotions, how to move their body, how to learn, how to respond to so many things in life. It is a wonderful and terrible thing that a child will copy exactly how its parents respond to their life experiences, and learn from those responses. Thus, children become almost exactly like their parents, responding in the same way, or having noticed that they are uncomfortable with the parents response, they find something that is different – unfortunately this is often usually opposite.

Many behaviours and traits that are thought to be genetic inheritance are in fact simply copied in an unconscious way. For instance (and, ignoring the specific details, this is a fairly common generic type of thing I find causes many cases of baby distress). One example ... some time ago I treated a baby who wasn't digesting its food very well – in particular the large intestine wasn't clearing the food very efficiently – and this part of the digestive system is innervated from the sacrum (rather than the Vagus Nerve). As I worked with the baby, its body relaxed, but its sacrum still felt disconnected. I checked the mother's sacrum, and found that a) it felt to be similarly disconnected, and b) she told me of an accident *during her primary school days* that had damaged her coccyx. When I started to remobilise the mothers coccyx (this is done externally through clothes in CST treatments, not internally), the baby's sacrum also started to mobilise. This is a really difficult issue, in that babies are *sometimes* not able to distinguish between good things to copy about their parents body usage, vs things that they really never should copy at all. And these continue to be unconscious responses throughout life unless they cause such difficulty that the person decides – at some stage in life – to do something to change that automatic response. The saving grace of this system is that children have an instinctive wisdom that often overrides or places question marks around the responses that their mirror neurons have detected. The tendency of babies and young children to pick up non-functional traits and patterns from their parents is not a universal thing – many children do not copy unhealthy patterns in any way. At the moment, with no clear evidence, I explain this to myself by thinking about internal and external validation. Children who require external validation would tend to pick up parents habits more indiscriminately, whereas children who are internally validated (i.e. refer to their own bodies to check how useful/appropriate something feels before copying it) would be less likely to copy non-functional patterns.

The power of this unconscious copying is perhaps most *overtly* apparent when children are allowed to be around working adults – something that we have almost completely expunged from western society. I am lucky enough to have found some very good Yoga, Taiji and Qigong teachers over the years, and one aspect of Taiji training is that there is far more *demonstrated* than described. This is precisely because we *best* learn body movements through applying the mirror neurons. So one part of a long-term training in Taiji (or any other martial art, Yoga, Qigong or similar body-based tradition) is that we train our mirror neurons to be more consciously active, or maybe to be more easily consciously activated. Thus, teachers have themselves to exhibit substantial skill and congruence in what they are teaching, and the greater that congruence and internal skill, the greater the “transmission” of the skill through activation of mirror neurons to the students. As the mirror neuron circuit becomes more consciously dominant, the movements become more and

more like those of the teacher. Provided that one drops into a body-felt-sensual style of learning (rather than remaining on an intellectual level of information gathering).

The ability to tune into the physical body-use of a skilled person is an extremely useful skill in itself. Most tasks have an inherent rhythm and type of mental-physical connection that is quite distinctive, that opens the body/mind to be most able to perform a particular set of actions, and which is the mark of an expert. If you watch an expert in anything, what is very apparent is the effortless effort. Each type of expert has a different internal rhythm which carries that effortlessness, and a different quality and degree of counterbalance and input between mind and body, and this again rides on the same rhythm of movement and action. This quality is particularly open to being connected to by using mirror neurons.

Mastery is an embodied state first and a state of mind second; and the state of mind follows naturally on from the embodiment. Some years ago I was fortunate enough to be invited to a local Taiko drum making session, which was being supervised by a retired master cabinet maker. I sensed that the man had a lot to teach, and deliberately tuned into his rhythm of movement, just as I would have connected with a Taiji or Qigong teacher. Meanwhile, he gave me a few simple jobs to do with a saw, while he continued to work steadily away in the background. He insisted on using hand tools rather than power tools. So, to take the top off an oak barrel and transform it into a drum rim, he used a hand auger to drill a series of holes large enough to take a saw. He then hand sawed in a perfectly smooth and perfectly evenly angled line round the barrel, while I did my sawing and chiselling. The whole experience was extremely soothing – his rhythm of work was slow and steady, but in a surprisingly short length of time the barrel looked like a drum, and then he started on the next one. I went home feeling pretty good, and it was only several months later that I realised the quality of my carpentry had gone up several notches – and the underlying experience of that improvement in carpentry was a similar working rhythm to the one I had been in the presence of. A comparable effect is often reported by people who have been in meditation workshops led by very experienced and skilled practitioners – just by sitting in the same room they are empowered to travel to places their normal everyday skills would not have been capable of. When they leave the workshop, the experience remains, providing them with a map of where they can go and something of how they got there. Rather like placing a book under your pillow and absorbing its essence without knowing the precise words.

What a child could do with this – from an emotional point of view, and from the point of view of learning life skills – is far greater. Children are naturally tuned into their mirror neurons far more than most adults. This is why contact even for a few short minutes with someone who is highly congruent in anything can enrich a child's life for – well – for life. The important factor is not some qualification in teaching – because that focuses on conveying information through conscious means. Rather, it is about the passing on of internal skills, internal relationships – what I think of as rhythm, congruence, presence, and mind-body coherence.

Mirror neurons and the development of language

One particularly important aspect of mirror neurons is that they link the two external primary senses – hearing and sight – to the musculoskeletal and visceral/emotional system. A good example of how this works is in the use and probably the development of language. We not only see people making particular movements, gestures and facial expressions – and convert that through mirror neurons to internal representations of movement and muscle tension (which then translate into emotive and other types of meaning). We also associate sounds with those movements and gestures. So (e.g.) the sound of a piece of paper tearing will evoke more or less the same neuron response as its visual presentation – provided of course that there is a memory of the action with the associated sound. There is also a strong link in the mirror neuron activity between the face and the hands. These two body parts have two particularly important functions – they are a major area for collection of sensory information and they are the major location of expression. One could say that expression (primarily through the hands and face) is the dissemination back to the outside world - of information about our internal state. So the hands and face are the primary location (approximately 80-90%) for information transfer both in and out of the human organism. And all of the external to internal information transfer takes place through the medium of mirror neurons. Research so far suggests that this accounts for between 20% and 30% of total brain activity.

Language theorists suggest that language started as a largely gestural form of communication – and mirror neurons pick up gestures – particularly mimed actions that literally represent or mimic real actions – and play them out internally. So a sound made at the same time as a gesture would become a form of shorthand for that gesture. When we hear speech without visual clues (e.g. from a radio) sound is not only affecting the speech centre directly - the mirror neurons for muscles in the tongue, face, pharynx and larynx are also firing, so we have a simultaneous internal representation of *how we would make those sounds ourselves*. This has substantial implications. Firstly, the strong internal link between hands and face in this mirroring arrangement makes sense of the modern trend of using “signing” (hand gestures developed as a language for deaf people) as an adjunct to speech therapy and preschool language training – and the success of use of signing in communication research with chimpanzees. It also puts the body-language communication used by (e.g.) horse whisperers into context. This gestural-analogical representation is most strongly present in languages such as Arabic – where particular combinations of constants are grouped in slightly different orders to produce a family of words with a commonality of meaning.

What I was particularly struck by was the idea that the *order* of words being processed by mirror neurons will have a significant impact on the way that their meaning is processed. This leads into differences in grammatical constructions between different languages. In English we use a typical sentence construction of <subject - verb - object> (e.g. I lightly stroked the sleepy cat). This presents the do-er; which would be internally represented... OK – that's me – regardless of whether the subject was “I” or “Joe Bloggs” or “my wife”. Then comes the action/verb... so the pre-motor areas of the brain take up the action or posture or gesture... But they have nothing to apply it to – no context until we state the object. It is worth remembering here that movements without contextual meaning only fire up the ventral premotor cortex, and do not create activity in the parietal lobe – there is no meaning, only a movement which could have *any* meaning. Compare this with Latin, where we have a sentence structure <subject – object – verb>. Here we

immediately set up a relationship : the subject and the object are placed together before any consideration of action is allowed. The action (once revealed by the unfolding sentence) is immediately contextualised. The psychological differences are substantial. English creates far more room for creative interpretation, humour, the setting up of double-takes and surprises. The action is freed up from the outside world, creating room for imaginative leaps. We leap in the air, and *then* decide what we are (e.g.) pouncing upon. Latin is far more grounded in action, and prepares the brain in advance for what is to come and what may be expected of it. Here we have a lion. There we have a goat. The lion jumps, eats. It is an uncompromising and pragmatic certainty. English also tends to place people momentarily in a relationship-less state, in which their action is completely internalised by the ego. On the other hand, Latin emphasises the relationship that exists before even suggesting what might be done with that relationship, both by the order of the sentence and the structure of each word used within it... Each language has its own peculiarities, and its own psychology. Whether the language evolved around a communal or even genetic psychology, or the psychology arises through the language structures – is an interesting question.

This slipperiness of language and its effect deep within relatively primitive and unconscious brain processes has been taken up by the creators of hypnosis (particularly Milton Ericsson) and NLP. A recent study of the effect of the use of present and future tenses in language¹⁴ showed that the use of future tenses tends to dissociate people from a particular action. So if you want to actually do something, it is important to speak of it “in the now” rather than as something in the future.

The issue of how we process numbers is a particularly tricky conundrum. Meaning, language and number were once the same thing. For anyone living before about 1500 AD in Europe (and particularly for people living before about 1000 AD in Europe and the Mediterranean/Middle Eastern region), each letter of the alphabet was also related to a particular number. So whenever anybody read a word, they also read a series of numbers, and whenever they read a number they were also aware of its accompanying associated letters. And both numbers and letters of the alphabet had symbolic meanings far greater and universal than their simple alphanumeric usage. One could say fairly accurately that numerology was deeply embedded in the psych of anyone with even a small amount of literacy. And most likely, they would construct sentences, or even construct words with the numeric sense of meaning as much in mind as other non-numeric meanings (if there were such things). This went to the most extraordinarily sophisticated lengths, and the entire set of Michaelangelo frescoes and floor tile patterns in the Sistine Chapel appear to be representations of alphabetic and numerical relationships with a spiritual meaning¹⁵.

Similarly, groups such as the Indo-Aryan culture that developed Sanskrit, the Hawaiian shamanic Huna culture and the Kototama tradition of Japan attributed meaning to specific syllables. So – rather as numbers can be cross-combined in several ways within a single word, a word could be constructed from several combinations of syllables, each having a different inherent meaning which came in addition to the meaning of the whole word. Similarly, many of the older hanzi/kanji (Chinese/Japanese pictograms) are combinations of smaller pictograms, each of which has its own intrinsic meaning. For instance, the hanzi for “to learn” is comprised of sub-hanzi that have a meaning something along the lines of “taking to heart”. Many languages (including English) also

14 <http://www.bbc.co.uk/news/business-21518574>

15 http://www.rosecroixjournal.org/issues/2006/New%20Folder/vol3_45_128_meeagan.pdf

have these compound words. All these are suggestive that the meaning that our deep brain attributes to everyday words – and numbers - goes far beyond the superficial meaning that we are now aware of. And that somehow, numbers are stored and recalled in a way that processes meaning through internal mirroring. i.e. via the musculoskeletal system and implicit movement patterns. This may be one reason why the playing of a musical instrument and mathematics go together so well.

God, Angels, Archetypes, Role Models & Parents

Of more immediate use and interest is the fact that *everything* that can be mirrored *is* mirrored within the brain in order to determine meaning. This is a particularly important principle – in that whatever we focus on is played back internally *as if we were actually doing it or experiencing it* so that the brain can determine its meaning. The specific ramifications of this are so important that they ought to be taught at school. If you happen to say anything about anybody (or anything), your mirror neurons play back that meaning as if all of it referred to personally you. Another way of describing the relationship between external and internal worlds, as mediated by mirror neurons is – **whatever we focus on, we get more of**. If we focus on the positive strengths of a person, then the brain plays that as if we are like that. So we can best learn by positively and actively admiring the particular traits or ways of holding knowledge that we wish to have ourselves. Yet another way this plays out is that – if we focus on “problems” or things that are “bad” or “ill” in other people, the brain tends to play this out as if it were happening to us. If you call somebody an idiot, some part of your brain thinks that it is *you* that is the idiot. And it gets worse. One perspective on the *positive* ways this mirroring can be used is laid out in an interesting and thought-provoking way in the free booklet “The Aloha Principle” by Serge Kahili King¹⁶. The scientists who discovered the principle of mirror neurons have publicly stated that they are “concerned” about the influence of pseudo-violence in our society (e.g. through the media of computer games, films, books and newspapers).

The issues raised above are particularly important in our choice of viewpoint and the focus of our views. As confirmed by historical evidence, we *need* both real people and benevolent spiritual beings to act as role models for our own best possible selves. It is important to have capable, powerful, ethical and congruent role models as we grow up so that we can have an internal somatic sense of how *we* would feel if we were performing that role in society or that particular task. This requires that real people do their best to fulfil the responsibilities of their particular public office, ideally so that their actions are those of the office's archetype. There is also a secondary requirement that we are capable of distinguishing the individual possibly fallible human from the archetype that s/he is personifying. The presence of mirror neurons underlines the reasons for the disproportionate destructiveness of all who wilfully abuse their office.

Likewise, the wilful attribution of fallibility and malfeasance to everyone in public office creates destructive messages through the mirror neuron system that has a high long-term cost to society. The fashionable rise of cynicism and distrust of anyone in public office is one that creates a lot of trouble for the future. The general message given to children that all adults are untrustworthy is,

16 <http://www.alohainternational.org/html/alohaspirit.pdf>

when looked at through the lens of mirror neurons – highly corrosive.

One might also consider the effect of using a language that objectifies processes as if they are something solid, and self-identifies with things that are not really part of the identity at all. For instance, “I have a cold” takes the process of the immune response to a virus/bacteria and makes it into something almost tangible. “I am ill” or “I am depressed” does something many times worse – it talks of illness or depression as something that has somehow become a part of the personality/identity. How much do these linguistic anomalies alter our daily lives and lock us into processes that should actually be very brief and unremarkable?

On a more positive and speculative note, it is worth considering that we can watch somebody who is highly skilled at any physical or social activity. And with a mindset that is open to receiving that information can then allow the mirror neurons to guide our own bodies into that level of skill. I also find myself asking what effect nature has on these mirror neurons. After all, we evolved in a natural world with natural shapes and movements – something in our brains must resonate with that far more than it does with the shapes and movements found in the modern world. Watching for instance a fish or a deer or the shapes of leaves and sunlight. All of these must also have some impact on the premotor cortex.

Switching them off... and letting them out

Mirror neurons operate in the **Pre**-motor cortex, and so, no matter how they are being used (for language, learning, empathising, etc) are in effect movements/responses waiting to happen.

There are many times when a direct repeat/mirror of the external world is not desirable, and so there also has to be a mechanism for inhibition of the mirrored actions that are constantly bubbling up in the pre-motor brain. When dogs start to bark, other dogs don't have much of a choice – they also have to bark, and the ability to not bark in response to barking nearby is something that has to be gradually assessed. Or the owner creates an override programme/response that has a higher priority.

So – this override may occur on three levels...

a) a programmed override in some specific circumstances, set up because another response has a higher (survival) priority.

b) a gradually assessed override, based on some kind of negative information feedback. If I keep barking, then the situation doesn't change. Eventually the unresponsiveness of the environment to frantic barking registers in the dogs brain... that the barking down the street is a non-event, and so a non-event does not require a response, and so the mirror is inhibited. Our brains definitely work on information-theory principles in many situations. It is change that is information, and non-change is non-information, whether the change takes the form 00000001 (silence then noise) or 11111110 (noise, then silence). I once lived near a busy railway line, and woke in a panic one night – to eventually realise that there was a rail strike, so the trains that should have come and made a

big clanking noise at 3.30am (which I would usually sleep through quite happily) were not going to do that. Something had changed.

c) conscious override – this is a high-end version of (a). We more-or-less consciously decide that we are going to inhibit our body's “instinctive” response. This is very much related to socialisation and social expectation. We are expected to behave in a way that is predictable and which matches a certain pattern, so going outside that pattern is socially risky. This level of inhibition is available on the same level as breathing – it may happen unconsciously or it may be a very conscious choice.

If the override/inhibition is not strong enough, due to factors such as loss of conscious control (e.g. schizophrenia, Tourette's syndrome), or particularly strong emotions, then the pre-motor content leaks out into the motor cortex. This has been recently documented for emotional response¹⁷, and it appears that (for most people!) the facial muscles are incapable of completely suppressing the pre-motor cortex content.

Another example of a subconscious override is when confronted with a person who is in such an unfortunate state that our body really does not wish to mirror that state. This occurs when presented with anyone who is seriously ill in any way, or is suffering from a particularly strong internalised emotions that the observer does not resonate with internally. For someone who is largely self-motivated, self-negating emotions will be difficult to embody, and positive emotions may also be difficult for anyone whose normal internal state is strongly self-negating. The response that arises to drive the override in these situations is disgust – either for other or for self. It is not necessarily a strong emotion, and may be itself overridden if compassion has a higher priority. It is particularly important to recognise disgust arising in this way so that it can itself be overridden. I had a strange visceral response for years that only occurred when I was in the presence of somebody in really severe abdominal pain, usually with some severe pathology causing the pain. Like something around my testicles and/or bladder had twisted itself round, accompanied by a fear/disgust response that is not conscious – it was always highly visceral, automatic and quite unexpected. As I've gradually become more conscious and compassionate (rather than reactive) over the years, this “gut reaction” has gradually faded away and now hardly ever happens.

¹⁷ Stephen Porter, Leanne ten Brinke and Brendan Wallace (2012) Secrets and Lies: Involuntary Leakage in Deceptive Facial Expressions as a Function of Emotional Intensity. *Journal of Nonverbal Behavior*. 36 (1), pp23-37, DOI: 10.1007/s10919-011-0120-7

Therapeutic applications

The main therapeutic applications of mirror neurons are

- literal mirroring to improve communication (described above)
- the use of “Counter-Transference” to communicate directly with and sense another persons body.
- re-educating the client to focus on resourcing material (both internal and external) rather than traumatising material

Counter-Transference is *probably (at least in part)* a process of mirroring, and is a state of simultaneous awareness of self, other and the space you/we are both in, such that emotions or even specific body sensations are immediately transferrable between individuals. If I am tuned into the counter-transference “field”, then (e.g.) when somebody gets a lump in their throat I will also feel some kind of lump in *my* throat. People familiar with using counter-transference recognise that there are advantages to this, and also dangers. The advantage is that one person experiences what is happening on an emotional level in another, and so have a very accurate empathic connection and understanding of that person. The danger is that this may be difficult to let go of, or may be too strong. So using counter-transference requires three quite specific skills :

1. being able to consciously choose to tune into (or not tune into) this field in the first place
2. being able to distinguish my own specific internal processes from those of another nearby person. This skill has two separate functions : So that I do not become confused about myself by their material, *and* so that I do not think that my material is coming from them.
3. being able to consciously de-tune or disengage form the counter-transference, so that anything I have temporarily chosen to allow to influence me is no longer affecting my body

We all inherently have the above three skills. But the skills can also be cultivated and strengthened if you are aware that they are there. The power of the mirror neurons is such that without these skills being used consciously, it is possible to be so deeply affected by others that we lose sense of ourselves, even at risk of catching a physical illness. Conversely, we can also be so caught up in our own ego that we think that others around us are feeling what we are feeling. So a conscious cultivation of mirror neuron skills, and a conscious recognition of how we process mirror information – how easily we can connect and disconnect and discriminate – is a very useful life skill.

Looking at this from a trauma angle, the tendency for people to vicariously retraumatise themselves by seeking out information and new experiences of the event that originally traumatised them starts to make sense if viewed from a mirror neuron/premotor cortex point of view. Trauma is shock which has become stuck in the system, and therapeutically, the primary way of dissipating it is to start just before the event and then proceed forwards in time but at the same time maintaining the patient in a resourced (rather than overwhelmed) state. Since the body does not understand time, but does understand process, if it is trying to repair itself, then it will also be

seeking out the start of the film, and then maybe hoping that when the re-run has a more satisfactory outcome. We play and play and play until we master the situation. Again there are overtones here of addictive gambling, computer games, etc. This simple discovery is in reality a profound window into the way that we process the world.

A few more notes on Transference and Counter-Transference

It is possible to explain the phenomenology of Transference and Counter-Transference in its entirety through the principle of Mirror Neurons. Transference is the client picking up clues from the therapist and then acting them out – i.e. leaking them back out into the motor cortex. And Counter-Transference is the detection by the Therapist that *his/her* system is behaving in an unfamiliar manner – because the mirrored body language of the client is starting to leak from the premotor cortex into action/the motor cortex. This provides some insight into empathy and the effect of consciousness as a useful tool to interrupt and censor unwanted mirrored gestures. It is both useful to acknowledge (and therefore be capable of using) this information *and* to not allow mirrored states to dominate our own internal state. Mirror neuron theory clearly shows why we tend to be more affected by people who have similar issues to us.

Once the processes of mirroring/transference are made conscious, they become use-able. To be most useful, there must be some strong sense of one's own self and the normal background somatic texture of the body - “how do I feel in myself?” in some detail. Then, when the attention is placed on that somatic detail *and* on the physical, spacial relationship between myself and another person, their somatic experiences can, to some extent, become my somatic experiences. Although I'm probably lucky enough (or not) to be good at finding this empathic link, this is a skill that anyone can apply provided that they cultivate a habitual sense of their own embodied presence. The flip side is that – being too tuned into another person can cause problems if one does not have a solid enough sense of embodied self to return to (so that the other persons somatic state can be forgotten).

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Links to Mirror Neuron papers by Vittorio Gallese, downloadable as PDF files:

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