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Studying the Brain Dynamics of Music, Movement, and Emotion

Affective perception and communication. Our intentions and behavioral decisions, the major portion of who we experience ourselves to be, are now clearly understood in the cognitive science and neuroscience field to crucially involve a major but long scientifically under-explored aspect of cognition -- our affective or emotional perception, feeling, awareness, and communication. As social beings, we (as well as animals) are faced with the highly important problem of knowing (i.e., somehow sensing) the intentions of others, often from quite sparse and transient sensory cues. To become aware of *the feelings of others* (the primary source and determiner of their behavioral intentions), we need to interpret subtle aspects of their behavior -- their facial expressions, their body position and gestural 'body language,' their vocal prosody and choice of words. Further, they (and we) may have reasons to hide feelings or to dissemble, traits also seen in pre-human social animals.

Modern neurophysiology has demonstrated the existence of brain support for such perception, first in the form of brain neural networks evidenced by ('mirror') neurons that are activated either by motivated self-movements or by motivated movements of others. However, 'mirror neurons' themselves cannot perform such 'reading' and interpretation -- their dynamics each play only tiny, isolated roles in large and complex brain network dynamics that serve this purpose. These dynamics must operate in 'real' time, often based on quick, spatially distributed, transient, multimodal sensory clues. However, discoveries of 'mirror neurons' and similar phenomena in human brain imaging suggest that we actually understand *both the actions and the feelings of others* by experiencing them 'as if' they were our own.

An important consequence of our long-evolved and evolutionarily crucial ability to read the feelings of others from their postural expressions, movements and voice qualities comes our ability to read human feeling expression from (or into) more abstract forms, movements and sound streams. It is this that has allowed *the experience of artistic feeling expression* through instrumental music and abstract art and dance to become such a socially and economically important and highly valued human activity. Music, in particular, is such a large part of our culture today because of the emotional 'grounding' and intensification it can induce in its affectively engaged listeners. Remarkably, both wordless instrumental music as well as song can produce deep experience of sympathetic or affective perception -- *but only in listeners who listen 'open heartedly' for expression of human feeling*.

Affective communication through music. Three major aspects by which composers and performers can communicate affectively through music are rhythm, melody, and harmony. Certainly we recognize the intimate relationship between a 'catchy' musical rhythm and physical dance. But perception of musical melodies also has an embodied aspect. For example, pianists playing an upward scale tend to lengthen each note ('climbing up' in pitch), whereas for downward scales may use shorter notes ('bouncing back down') (M. Clynes, personal communication). The exact sense in which melodic contours are 'embodied' in an imaginative space that includes some form of 'gravity' has not been modeled. Clearly, studies of expressive movements to music might prove valuable in constructing such a model.

Here I focus on the harmonic aspect of music, which uses a collection of harmonic pitch relationships that is remarkably universal. The octave (2/1) identity is fundamental to nearly all musical cultures, as exemplified by men and women being heard by us as singing 'in unison' when in reality their voices are an octave (2/1) apart in pitch. Thirty years ago now, I played well-tuned and slightly mistuned melodic (non-simultaneous) octaves (each two sine tones) to a group of music students, asking them to imagine these two-note phrases as representing a statement by one person (via the first note) and the second note as representing the repetition of that statement by another person (Makeig, 1983). I then asked them to describe, in each case, *to what extent the second person was convinced of the first person's statement.* This design was inspired by the work of Helen Bonny (1990) to develop a method, Guided Imagery through Music (GIM), that uses a form of semi-hypnotic suggestion to heighten a listener's experience of carefully selected classical music, the listener's resulting emotional and imaginative experiences then used in psychotherapy by the GIM therapist.

The verbal responses in the actual experiment, when sorted by pitch distance between the two tones, exhibited a finely graded match between exact pitch ratio and imagined feeling tone of the second 'speaker,' a dramatic example of our ability to glean affective meaning even from minimal, and here unusually tuned laboratory (sine tone) stimuli -- *when we imagine that they represent personal feeling expression.* Further, participants' statements were typically accountable by a low-dimensional mapping between octave (mis)tuning and feeling: even slightly narrow octave tones were heard as the utterance of someone who was highly doubtful of the truth of the first tone/statement, whereas slightly wide octave tones were heard as utterances of someone who strongly endorsed the first tone/statement 'with energy and enthusiasm.'

The use of suggestion and guided imagery to heighten emotional experience is still rare in the scientific study of affective perception and communication. The 'octave tuning' experiment describe above illustrates the power of this approach; given the same pairs of sine tones and simply asked to describe them, the music student participants would likely have used very few affective terms, instead focusing on matching their perception to learned categories (e.g., 'Two notes an octave apart, the second note a bit sharp.'). If this study were to be replicated using musically naïve participants, they would have no learned categories and corresponding vocabulary with which to give an objective description of their percepts, but would likely give either simple physical descriptions (e.g., 'Two clear-sounding tones, the second lower than the first') or, again, interpretable (and still finely graduated?) descriptions of their affective perception.

To create affectively communicative music, of source, composers and performers simultaneously use all three major elements of music - rhythm, melody, and harmony. While these are used somewhat differently in different musical cultures, the use of harmonic relationships to convey feeling by composers of Western 'common practice' music appears to transcend narrow musical style boundaries -- witness the current widespread appreciation for Western pop/movie music and its locally inflected musical 'dialects' around the world. This spread of appreciation and influence is based in part on its use of near-universal harmonic principles. Of the highly developed musical cultures perhaps only the gamelon music of Indonesia does not base its harmonic relationships on perfect fifth (3/2) frequency ratios. Most musical cultures also use harmonic major/minor thirds (6/5/4), the resulting 2-D 'web of fifths and thirds' thereby forming an underlying harmonic fabric developed most fully in Western ('common practice') music. I believe that the wide and easy spread of appreciation for this music is in part because its affective palette arises from *a single, deep mapping between its harmonic space (the 2-D web of fifths and thirds) and the principal two dimensions of affect,* exemplified by the 2-D 'Evaluation X Potency' model of Charles Osgood (1956) -- a concept I first found in the earlier work of a controversial French Indophile, Alain Danielou, but have so far tested only in small part (Makeig, 1982; cf. Oelmann, 2003).

Brain dynamics of affective perception. Neurophysiology was long (through the whole 20th century, and still in large part today) hindered by its fixation on single-cell dynamics, with human studies thereby discounted because of the unavoidably invasive nature of single-neuron recording. Non-invasive electrical brain imaging (EEG), on the other hand has long been hampered by a failure to use an electrical forward head model to model and visualize the recorded data within the original brain space, its actual origin - instead measuring only the raw scalp signals that by simple biophysics must each mix contributions from many brain areas (Makeig, 2004).

At the Swartz Center for Computational Neuroscience I and colleagues have been working to build and disseminate methods for treating high-density EEG data as a true functional brain/cortical imaging modality in which some scales of activity within distributed cortical networks can be seen, measured, and modeled. We are also pioneering the development of a new simultaneous brain/body-imaging concept we call 'mobile brain/body imaging' or MoBI (Makeig, 2009). This new paradigm combines high-density EEG and body motion capture with recording of eye gaze and task behavior in subjects who are performing naturally motivated actions -- and/or interactions -- in normal 3-D spaces.

Our recent studies have shown that adequate EEG brain dynamic measures can reveal the ways in which brain electrical activity supports affective perception and imagination, as well as unveiling the dynamic cortical network support for experience of (e.g.) rhythmic complexity (Iversen, in preparation). We have also recently learned something about how simple gestures can express musical pulse and feeling to others, as in dance and orchestral conducting (Leslie, 2014). But these experiments only touch the surface of a rich body of experimental evidence and investigation that needs to be brought to bear to develop scientific understanding affective perception, communication, and empathy -- and its brain dynamic support. I propose further studies to clarify the ways in which our brains support our affective perception, imagination, experience, and communication, through music and movement. I expect these studies to clarify the brain basis for our intuitive understanding that emotionally expressive music, emotionally expressive movement, and emotional expression itself are intrinsically linked, not only in the vast web of human associations but also by strong, low-dimensional mappings that we can explore *by applying the scientific method through studies of affective perception and communication*.

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