

Music, Cognition, and 4D

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- ❑ 3D and 4D Models of Cognition
 - ❑ 4D Models of Music Cognition
 - ❑ Quaternions, Fractals, and Thought

“Search for the Fourth Dimension”

Salvador Dali

(Painting, 1979)



Introduction

How do space and music fit together?

Strategic points:

1. Quaternion space is a 4D space. So a quaternion is typically a 4D object.
2. Melody has been described by some researchers as being a 3D, 4D, or even 5D object.

Let us look at some spatial cognitive research findings and conjectures.

General Cognition and Music Cognition

Preliminary Comments

- ❑ The foundation of any mathematical model of music is harmony. (The mathematical model of music is based on “tonal attraction.” It’s a gravity model--gives potential values to each tone for movement toward the tonic note.)
- ❑ Music in the brain versus in the air:
 - Acoustics – Sound in the Air
 - Acousmatics – Sound in the Brain – **This one is our interest.**
Dimensionalities of phenomena in the brain may be different than in acoustics.

4D/Quaternions and Music Cognition

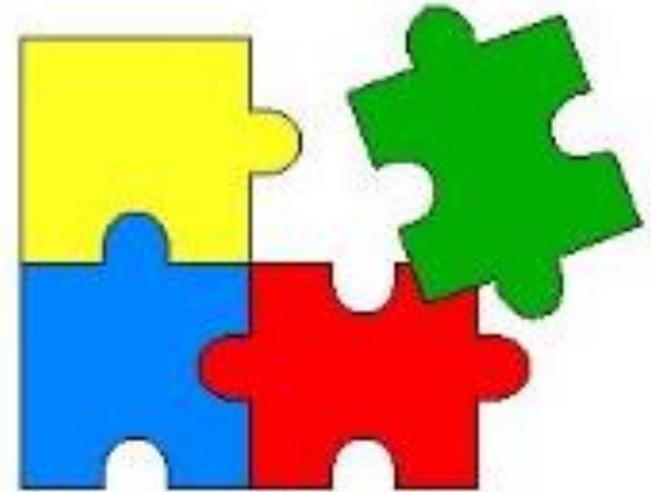
Preliminary Comments

- ❑ Some composers have used quaternions, other hypercomplex numbers, and projective geometry relationships to create their compositions.
 - Algebra, including quaternions: Gerald Bolzano, Guerino Mazzola
 - Projective geometry: David Lewin
- ❑ We can consider music to be the first Virtual Reality (VR) environment experienced by human civilization.
- ❑ Melodies are musical forms in a tonal space.
 - Melodies are geometric shapes reflecting paths taken while traversing a tonal attraction space. Stronger attractions come from shorter tonal distances, measured in harmonic steps of separation of two notes, based on overtone series.

3D and 4D Models

3D **General** Cognition Research Models

- 3D Virtual Retinoid Space with Self in Center (Arnold Trehub, 1991, 2005)
- Default 3D Multisensory Space in Parietal Lobe, supported by thalamus (Jerath and Crawford, 2014)
- Supramodal Mental Rotation of Melody and Visual Objects in Parietal Lobe (Marina Korsakova-Kreyn, 2005)



4D **Music** Cognition Research Models

- 4D Distances of Musical Keys From Each Other (Krumhansl & Kessler, 1982)
- Possible 4D Nature of Melodies? (Gilles Baroin, 2011; others)
- 4D/5D Melody of the Text (Mike Mair, 1980)

General Cognition – Trehub Retinoid Model

- ❑ Trehub theorizes a “retinoid space” located in the inferior parietal lobe of the brain.
- ❑ “Two key assumptions of the retinoid model are:
 - (1) visually induced neuronal excitation patterns can be spatially translated over arrays of spatiotopically [3D] organized neurons, and
 - (2) excitation patterns can be **held in short-term memory within the retinoids** by means of self-synapsing neurons called autaptic cells.”
- ❑ **“I made these assumptions originally because they provided the theoretical grounding for a brain mechanism capable of processing visual images in 3D space very efficiently and because they seemed physiologically plausible.”**
(Trehub, 1977, 1978, 1991).
- ❑ **“More recent experimental results provide direct neurophysiological evidence supporting these assumptions.”**
Arnold Trehub: Space, Self, and the Theater of Consciousness (2005)

General Cognition – Trehub Retinoid Model

General observations:

- As an integral part of the larger neuro-cognitive model, **the retinoid system is able to perform many other useful perceptual and higher cognitive functions.** In this paper, I draw on the hypothesized properties of this system to argue that **neuronal activity within the retinoid structure constitutes the phenomenal content of consciousness and the unique sense of self** that each of us experiences.

General Cognition – Trehub Retinoid Model

Here are Arnold Trehub's views on the potential of the retinoid space in the brain to provide 4D capabilities:

“I'm not knowledgeable enough to respond to your detailed observations about music, but I must point out that all autaptic-cell activity in retinoid space is 4D because autaptic neurons have short-term memory.

This means that there is always some degree of temporal binding of events that are "now" happening and events that happened before "now". The temporal span of such binding probably varies as a function of diffuse activation/arousal.

The temporal envelope of autaptic-cell excitation and decay defines our extended present. This enables us to understand sentences and tunes.”

Personal communication

ResearchGate.net

Where I Met Arnold Trehub and Many Others

- ❑ Free, minimal requirements
- ❑ Paper repository
- ❑ Lively question discussion groups
- ❑ 5 million members
- ❑ Heavily international
- ❑ Internal messaging is available between members

General Cognition – Jerath & Crawford

Parietal/Thalamus Model

Jerath, R. and Crawford, M. W. (2014). Neural correlates of visuospatial consciousness in 3D default space: Insights from contralateral neglect syndrome. [Consciousness and Cognition](#), 28, 81–93.

Summary:

- ❑ They propose that the thalamus is a central hub for consciousness.
- ❑ “We further suggest that the thalamus generates a dynamic default three-dimensional space by integrating processed information from corticothalamic feedback loops, creating an infrastructure that may form the basis of our consciousness. Further experimental evidence is needed to examine and support this hypothesis, the role of the thalamus, and to further elucidate the mechanism of consciousness.” ...
- ❑ The thalamus may reimage visual and non-visual information in a 3D default space.
- ❑ **3D default space consists of visual and other sensory information and body schema.**
- ❑ They state that their default space is equivalent to Trehub’s retinoid model.

General Cognition – Korsakova-Kreyn

3D/Parietal/Supramodal Model Based on Mental Rotation

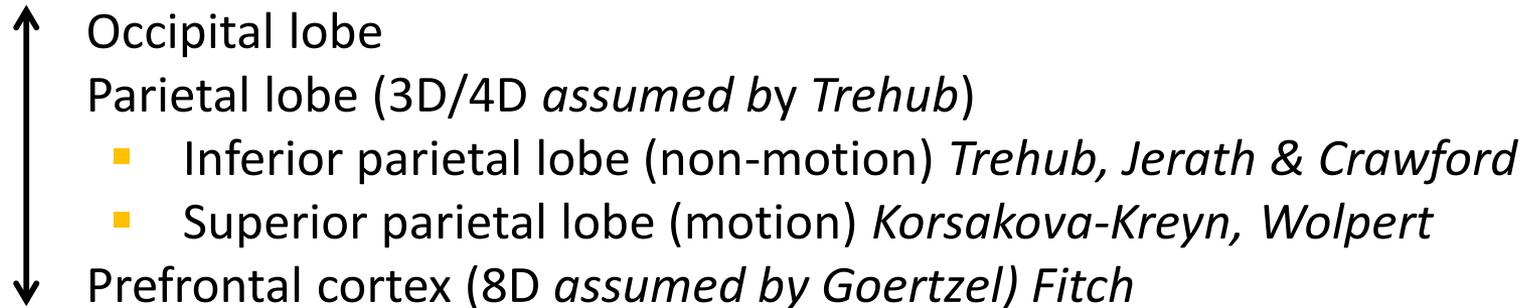
- “The parietal lobes interpret sensory information and are concerned with the ability to carry out and understand spatial relationships. It was found that the right superior parietal lobe plays an essential role in mental rotation (Harris & Miniussi, 2003; Alivastos, 1992). There is neurophysiological evidence that lesions to the right parietal lobe impair mental rotation abilities (Passini et al, 2000) and that the superior parietal region seems to play a ‘major role in the multiple spatial representations of visual objects’ Jordan et al (2001).”
- **“I hypothesize that perhaps the brain reads both music and spatial information as a signal-distribution within system of reference notwithstanding the modality of the signal. Recent imaging studies suggest that the parietal lobe is an integral part of a neural lateral prefrontal–parietal cortices circuit that is critical in cognition.”**

Brain Regions and 3D-4D-8D

Brain Regions: Facts and Relationships

The thalamus connects all brain regions. (Possible 4D-8D conversions)

Perception uses downward flow; imagination uses upward flow. (Dentico)



Long-term memory formation and spatial navigation.



Reciprocal management of declarative/implicit and episodic/explicit knowledge



Brain Regions and 5D-8D

John Gardiner and associates use EEG data as evidence of higher-dimensional fractal signals in the brain, ranging fractionally from 5D to 8D.

This evidence supports my own 4D/8D dimension-converting model of the thalamus.

Gardiner speculates that quantum gravity effects are being processed in the higher dimensions, since they are assuming that only 4D is needed to represent the real world.

Fractal Brain as Quantum Computer (2010)

Site of Consciousness

- Terry Marks-Tarlow suggests that perhaps local consciousness pictures arise in different areas of the brain, such as the parietal lobe and the thalamus, which are then intercommunicated, producing an overall consciousness.

- *Personal communication*

4D/Quaternions and Cognition – A Question

Do quaternion-like mechanisms actually exist in the brain?

How might quaternion and other hypercomplex system operations be carried on by the brain?

- ❑ Perhaps rotation is performed by repeated small, controlled rotational increments. (Research shows that task time is correlated with angle size – amount of rotation.)
- ❑ The brain can by nature generate many geometric functions.
 - Computations by the brain, of visualized geometric mathematical patterns, have been induced through psychedelic drugs by Jack Cowan, University of Chicago)

Quaternions and Carl Jung, and later Jung-Inspired Math-Exploring Researchers

Science and math – rich involvement

- Carl Jung (psychologist) - Wolfgang Pauli (inventor of quantum physics) correspondence (1932-1958) leads to interpretation of space/time
 - Space-time: 3-and-1 dual interpretation, 3D space vs parallel past-present-future dimensions

- Bernd Schmeikal (social science mathematician, Vienna).
 - Schmeikal says that synchronicity (coincidence without a cause) is an orthogonal augmentation to the conventional time-space path.

Bernd Schmeikal

Four Forms Make a Universe

Excerpts from Abstract:

- ❑ Describes a representation of space and time within the cognitive system which is both inner and outer (Kant is only inner).
- ❑ Uses Clifford algebra and iterant algebra (Lou Kauffman).
- ❑ Deals with forms of nature, matter, space, and time.
- ❑ There is an oriented logic core within space-time algebra.
- ❑ When we conceive the existence of a few features like polarity between two appearances, identification and rearrangement of the latter as basic and primordial to human cognition and construction, the intelligence of space-time is prior to cognition, as it contains within its representation the basic self-reference necessary for the intelligible de-convolution of space-time.
- ❑ Thus the process of nature extends into the inner space.
- ❑ *[from a reviewer]:* ...it is a successful attempt to deduce structures from the nature or the universe by logical considerations. The space is considered a structural event.... It is an important paper with valuable connections to physics, logics, philosophy and mathematical structures (algebras). **It justifies studying Clifford algebras as a natural phenomenon.**

Schmeikal, B. (2014). Four forms make a universe. Conference paper. Creative Commons license, CC-BY-SA. Researchgate

https://www.researchgate.net/publication/269108806_Four_Forms_Make_A_Universe

4D Quaternion Higher-Level Cognitive Map

Terry Marks-Tarlow

- ❑ The key brain structure is the hippocampus, historically viewed as the seat of episodic memory, but more recently recognized as the seat of imagination and mental time travel forward as well. In the rat, the hippocampus has been studied as the seat of spatial navigation.
- ❑ Researcher Gyorgy Buzsaki has identified 1- and 2-dimensional maps formed by individual place cells. 1-D maps are formed by touch as the rat moves in straight lines (like dead reckoning of sailors). 2-D maps are formed when the rat explores a single point in space from the perspective of many intersecting lines. Once this occurs, the rat is able to calibrate internal sensory motor systems with external features, such that it becomes oriented in physical space and no longer needs to keep track from the inside in order to navigate. Instead, the rat can use outside information, like the sight of a familiar water dish, to navigate around. Buzsaki makes the link from rats exploring physical space to humans encoding episodic memory.
- ❑ Marks-Tarlow believes part of the jump here involves the use of higher dimensional 3-D and 4-D maps in much the same way: a single episode that is remembered concretely involves 3-D grids. Multiple episodes that explore the same territory from a variety of perspectives move onto higher dimensional spaces that allow greater abstraction by removing the event from its concrete context.

Personal communication (February 7, 2015).

Quaternions and Carl Jung, and later Jung-Inspired Math-Exploring Researchers

Terry Marks-Tarlow on quaternions:

- “Quaternions are products of the hypercomplex plane consisting of one real and three imaginary axes. If imaginary numbers do relate to abstract processes in consciousness, and more specifically to the fuzzy zone between body and mind, then because they are three-dimensional shadows of four-dimensional space, quaternions may provide some clues as to the internal landscape of higher dimensional thought.”

Semiotic Seams: Fractal Dynamics of Re-Entry (2004)

- This brings us back full circle to Ada Lovelace in 1843:
How can using multiple imaginary numbers help us represent the relations and operations of aesthetics (and thought) in a scientific way – and re-enact them on a computer?
- I believe there is a great arc of thought connecting the ideas of Ada Lovelace with the newly emerging field of social robotics (the ability of advanced robots to relate comfortably and constructively to people).

Underpinnings of Music: Spatial, Motor, and Affective Pillars

- ❑ Cognitive: Navigation and “Where is the Self?”
(*Trehub, Marks-Tarlow, Buzsaki, Damasio, Mair*)
- ❑ Motor: Locomotion and experience of travel
(*Kevin Behan, Daniel Wolpert*)
- ❑ Emotion and Body State: Tension/relaxation polarity
(*Krumhansl, Panksepp, Korsakova-Kreyn*)

Music Cognition – Krumhansl & Kessler (1982)

Derived 4D Perceived Space of Musical Key Distances

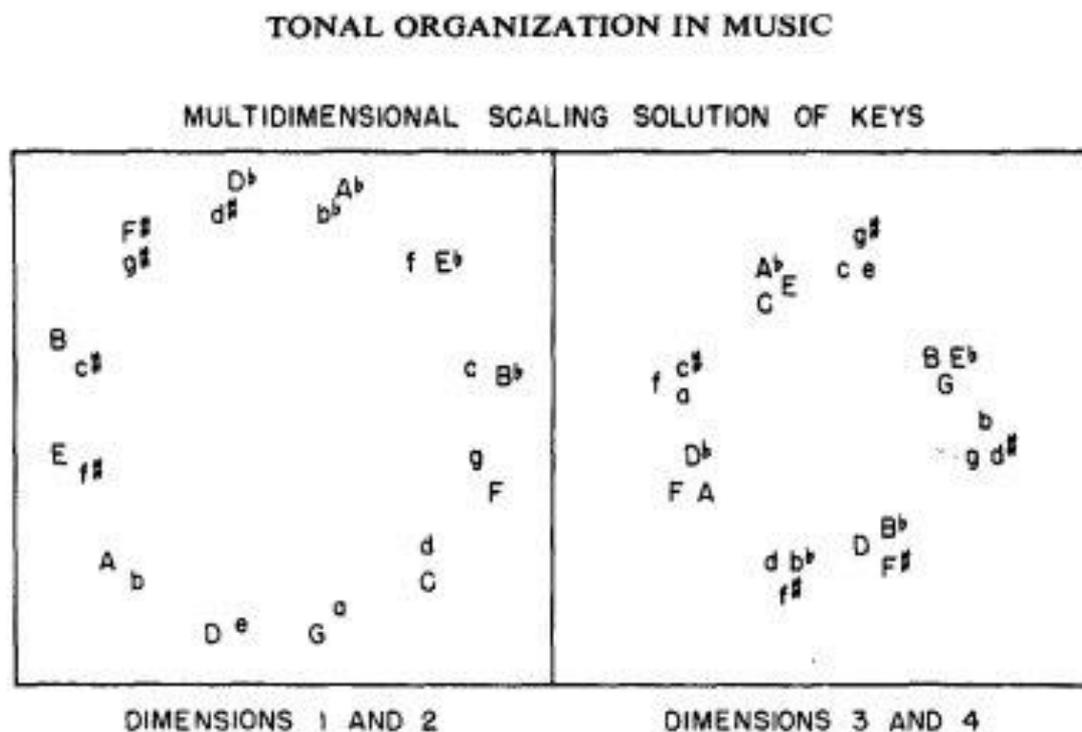


Figure 4. The four-dimensional multidimensional scaling solution of the intercorrelations between the 24 major and minor key profiles (stress = .017). (The projection of the solution onto the first two dimensions is shown on the left. In this projection the circle of fifths for major and minor keys was obtained. The projection onto the last two dimensions is shown on the right. Major and minor keys separated by an interval of a major third were represented as single points in the solution. Each major key was located next to its parallel minor key on one side and its relative minor key on the other. Similarly, each minor key was flanked by its parallel and relative major keys.)

Music Harmony Modeling – Gilles Baroin (2011)

Via Unit Hypersphere Quaternions

- ❑ Performs a 4D trajectory of musical notes
- ❑ Dissertation: Applications of graph theory to musical objects: Modeling, visualization in hyperspace. (University of Toulouse)

- ❑ DEMO:
ACT 5 FOUR DIMENSIONS : THE PLANET-4D PITCH AND CHORDAL SPACE

We now visualize the pitch space in a true four-dimensional space, by projecting it into our 3D space and letting it rotate around two 4D Axes. The same rotating ball that symbolizes the current position, never moves while the model rotates. Thanks to this technique, the model appears to be deforming within a 3D sphere. That reinforces the feelings of symmetry for the spectator.

- ❑ <http://youtu.be/MGCIPZyaiuw>

Music Cognition – Are Melodies 3D or Perhaps 4D?

The Melody of the Text (Mike Mair)

- ❑ “Even though the **speech trajectories** capture virtual world models rather than actual objects on four-dimensional trajectories (like a prey animal moving in the environment), I suggest that the trajectory of speech with movement [*gesture, including ballistic and oral-facial*] is non-verbal, the product of the core brain forming the core to the speech act. The ‘point’ is the point. A growth point is defined as the ‘initial form of thinking out of which speech-gesture organization emerges’. (McNeill) It might also be called the ‘projection point’.
- ❑ The core brain mechanisms underlying human natural story telling can now be glimpsed. Damasio’s core brain text generator in action describes the nonverbal internal structure of gesturing behaviour in speech with movement. It may have functioned projectively on 4D-space time for probably millions of years. Additional control of outcomes is achieved by adding more dimensions or variables to the modeling process, up to our present limit of 7+/-2.”

Mike Mair, The Melody of the Text – Revisited (c. 2002-2014).

Kevin Behan -- Trajectory and Music

- ❑ *Panksepp*: “Of course, happiness and sadness work together, and the most moving music allows the two processes to be blended in such a way as to magnify our sense of ourselves as deeply feeling creatures who are conscious inheritors of the tragic view—the ability to see hope and grace in the midst of despair. It may be that the physiological possibility for the experience of chills is established **when music joins our deepest opposing emotional potentials** within the cradle of consciousness.”
- ❑ *Behan*: While I’m very attracted to these kinds of interpretations that root higher cognitive processes to basic bodily processes, I still feel that a deeper explanation can be found in the locomotive circuits because before there were parent/offspring relationships, there were predator and prey relationships, and there was the absolutely fundamental mandate of moving the body from point A to point B so as to intercept an object of attraction.
- ❑ This would also be more compatible with the research of Dr. [Daniel] Wolpert who states that everything about the brain is dependent on locomotion. Therefore I believe the emotional affects are not predicated on survival mechanisms or neurological circuitry hardwired in the Central Nervous System, but rather **how the body and brain interplay on a much deeper level**, specifically how to move the body from point A to point B.
- ❑ *Kevin Behan – Why We Like Sad Music, Part II, blog interview*

Ben Goertzel – Internal Social Actors & Mirrorhouses



- ❑ “Recent psychological research suggests that the individual human mind may be effectively modeled as involving a group of interacting social actors: both various subselves representing coherent aspects of personality; and virtual actors embodying ‘internalizations of others.’”
- ❑ “Recent neuroscience research suggests the further hypothesis that these internal actors may in many cases be neurologically associated with collections of mirror neurons.”
- ❑ “Taking up this theme, we study the mathematical and conceptual structure of sets of inter-observing actors, noting that this structure is mathematically isomorphic to the structure of physical entities called ‘mirrorhouses.’”

Ben Goertzel – Quaternions (4D), Octonions (8D), and Mirrorhouses

“Mirrorhouses are naturally modeled in terms of abstract algebras such as quaternions and octonions (which also play a central role in physics), **which leads to the conclusion that the presence within a single human mind of multiple inter-observing actors naturally gives rise to a mirrorhouse-type cognitive structure and hence to a quaternionic and octonionic algebraic structure as a significant aspect of human intelligence.**”

Fourth Dimension – Cognition & Neuroscience



- 2009 – Mike Ambinder, Human four-dimensional spatial intuition in virtual reality.

“Research using [virtual reality](#) finds that humans in spite of living in a three-dimensional world can without special practice make spatial judgments based on the length of, and angle between, line segments embedded in four-dimensional space.^[12]”

“The researchers noted that “the participants in our study had minimal practice in these tasks, and it remains an open question whether it is possible to obtain more sustainable, definitive, and richer 4D representations with increased perceptual experience in 4D virtual environments.”^[12] Wikipedia

Ambinder M. S., et al (2009). Human four-dimensional spatial intuition in virtual reality. *Psychonomics Bulletin & Review*, 16, 5, 818-823

<http://link.springer.com/article/10.3758%2FPBR.16.5.818>

Fourth Dimension Summary – Cognition & Neuroscience

Human cognition appears to have an inherent capacity to engage in 4D multisensory processing. This is reflected in the research of:

- ❑ Arnold Trehub – 4D autaptic cells with short-term memory Krumhansl & Kessler -- 4D Perceived Space of Musical Key Distances
- ❑ Mike Ambinder – many people can make judgments about lines and angles in a 4D space
- ❑ Mike Mair – 4D/5D Melody of the Text experiments
- ❑ Terry Marks-Tarlow – 4D Quaternion Spaces in Cognition
- ❑ Ben Goertzel – 4D and 8D Mirrorhouse models of internal actors
- ❑ Gilles Baroin – 4D Melody – Pitch Trajectory in animation, based on quaternion projection of elements
- ❑ Bernd Schmeikal -- 4D basis (tessarines/quaternions) of logic and time-space algebra; Clifford algebra shapes seem to be objects in nature.
- ❑ John Gardiner and associates use EEG data as evidence of higher-dimensional fractal signals in the brain, ranging fractionally from 5D to 8D.

Closing Quotes – Value of Generalization Using Quaternions

- ❑ One of the most important ways development takes place in mathematics is via a process of generalization. On the basis of a recent characterization of this process we propose a principle that **generalizations of mathematical structures that are already part of successful theories serve as good guides** for the development of new physical theories.
- ❑ The principle is a more formal presentation and extension of a position stated earlier in this century by Dirac.
- ❑ **Quaternions form an excellent example of such a generalization and we consider a number of ways in which their use in physical theories illustrates this principle.**

(Ronald Anderson, 1992)

End of Presentation

