PSYCO 354
Classical Music and the Cognitive Sciences

A Musical Analogy
Classical Cognitive Science And Classical Music
Connectionist Cognitive Science And Classical Music
Embodied Cognitive Science And Classical Music
Hybrid Theories

A Musical Analogy

- **One way to explore relationships between the cognitive sciences is to consider how they approach the same topic, for example the cognition of classical music**
- **Part of this material involves having a little fun with the material by using properties of music to highlight characteristics of cognitive science via analogy:**

Classical Cognitive Science	Connectionist Cognitive Science	Embodied Cognitive Science
Austro-German Music	Romantic Classical Music	Modern Classical Music

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Classical Analogy

- **We will begin by pursuing a striking analogy between classical cognitive science and classical music in the Austro-German tradition**

	Classical Cognitive Science	Classical Music
Formal structures	Logicism	Tonality, sonata-allegro form
Meaningful representations	Rationality	Musical messages
Disembodiment	Mental representations separate from world	Mental compositions separate from world
Central control	What rule to use next?	Conductor and score
Reacted against	By connectionism and embodied approach	By romantic and by modern music

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Musical Logicism

- **A musical score is obviously a formal representation of a musical piece**
- **In Austro-German classical music, the formalism extends far beyond this, to the structure of entire musical pieces.**
- **A musical offering is expected to have a particular structure (Copland, 1939), "the planned design that binds an entire composition together"**
- **Example: Sonata-allegro form**

Aaron Copland

Exposition (A)			Development (B)	Recapitulation (A)		
a	b	c	abc	a	b	c
First theme in tonic key	Second theme in dominant key	Closing theme in dominant key	Free combination of the three themes, and new material, in foreign keys	First theme in tonic key	Second theme in tonic key	Closing theme in tonic key

Table 2-1. The hierarchical structure of sonata-allegro form.

Musical Rationality

- **Classical cognitive science is committed to <u>rationality</u>: the notion that behavior is a consequence of the contents of mental representations**
- **Classical music is also content-laden ; its structure is intended to communicate some meaning"**
- **My own belief is that all music has an expressive power, some more and some less, but that all music has a certain meaning behind the notes and that that meaning behind the notes constitutes, after all, what the piece is saying, what the piece is about" (Copland, 1939, p. 12)**

Aaron Copland

The Disembodied Mind

- **Classical cognitive science employs a sense-think-act cycle, but emphasizes thinking at the expense of sensing and acting**
- **This disembodies the mind, separating it from the world, which is consistent with its Cartesian roots**
- **Classical music is similarly disembodied**
  - Mozart "carried his compositions around in his head for days before setting them down on paper" (Hildesheimer, 1983): in a letter that he wrote to his father in 1780, Mozart noted that "everything is composed, just not copied out yet."
  - Copland (1939, p. 22) observes that "a current idea exists that there is something shameful about writing a piece of music at the piano."
  - Joe Jackson (1999 liner notes for *Symphony No. 1*) recalls that "I had a handful of very simple musical themes in my head and wanted to see if they could be developed and transformed throughout four whole movements."

Mozart

Joe Jackson

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Central Control

- **Classical cognitive science must always be concerned with *the problem of what to do next***
  - "An adequate theory of human cognitive processes must include a description of the control system-- the mechanism that determines the sequence in which operations will be performed" (Simon, 1979)
- **Classical music employs a form of central control: the composer**
  - "The conductor acts as a guide, a solver of problems, a decision maker. His guidance chart is the composer's score; his job, to animate the score, to make it come alive, to bring it into audible being" (Green & Malko, 1975)
- **A classical score also imposes central control**
  - "Given the centrality of musical notation in the discourse of classical music, a parallel notion is that of Texttreue: fidelity to the written score (Benson, 2003)

Bruce Benson

Methodological Solipsism and Music

- **Disembodiment is a recurrent, tacit theme of classical cognitive science – a consequence of *methodological solipsism***
  - "Methodological solipsism in psychology is the view that psychological states should be construed without reference to anything beyond the boundary of the individual who has those states" (Wilson, 2004)
- **Classical music endorses methodological solipsism, in terms of the role of the audience: *A traditional piece is not defined by the audience that listens to it* – another form of disembodiment**
  - Composer Arnold Schoenberg believed that the audience was "merely an acoustic necessity – and annoying one at that" (Benson, 2003)
  - Composer Virgil Thompson defined the ideal listener as "a person who applauds vigorously" (Copland, 1939)

Arnold Schoenberg

Virgil Thompson

Classical View: Seeking Musical Structures

- **How is classical cognitive science reflected in its study of musical cognition?**
- **The classical approach to musical cognition assumes that listeners construct mental representations of music**
- **Sloboda (1985, p. 3) argues that "a person may understand the music he hears without being moved by it. If he is moved by it then he must have passed through the cognitive stage, which involves forming an abstract or symbolic internal representation of the music" (Sloboda, 1985, p. 3)**
- **A classical theory must provide an account of such mentally constructed entities. How are they represented? What processes are required to create and manipulate them?**

John Sloboda

The Musical Mind
The Cognitive Psychology of Music
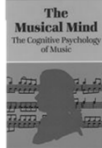
Classical Research Example: Tone Probe Method

- **Krumhansl and Shepard (1979) used variations of the tone probe method to study musical representations**
- **Play a musical context**
- **Play a final tone**
- **How well does final tone complete or fit in with the context?**

Carol Krumhansl

Roger Shepard

Tone Probe Method: Basic Result

- **Judgments of context completion reflect preference for particular notes depending on relation to musical scales**
- **This reflects organizing sound stimuli according to cognitive, musical, principles**
- **"The perceptual interpretation of sounds as music depends upon the categorical assimilation of those continuously variable sounds to an underlying discrete set of tones" (Krumhansl & Shepard, 1979, p. 592)**
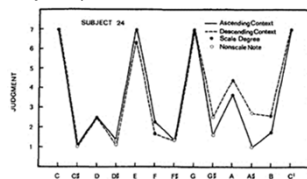
Musical Spaces In The Mind

- **What kind of mental structures are used to organize music?**
- **Krumhansl (1979) had subjects rate the similarity of tone pairs in a particular context and performed MDS on the data**
- **"The perception of music depends not only on psychoacoustic properties of the tones, but also on processes that relate the tones to one another through contact with a well-defined and complex psychological representation of musical pitch" (Krumhansl, 1979, p. 372).**

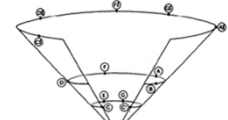Fig. 2. The two-dimensional multidimensional scaling solution of the similarity data.   Fig. 3. The idealized three-dimensional conical configuration.

Classical Music: Structure and Process

- "All musical thinkers agree that there is such a thing as a musical syntax, comparable to a descriptive grammar of speech" (Bernstein, 1976, p. 56)
- Lerdahl and Jackendoff have developed a generative grammar that describes how well-formedness rules are used to recursively organize musical pieces
- "When hearing a piece, the listener naturally organizes the sound signals into units such as motives, themes, phrases, periods, theme-groups, and the piece itself" (Lerdahl & Jackendoff, 1983, p. 12)
- Classical theories appeal to musical structure and processes that manipulate them

Reacting Against The Classical

- Classical cognitive science is a dominant, status quo, view
- However, it has generated movements that are strong reactions against the classical approach
- *Connectionists* are concerned about biological plausibility, and react against the formal basis of logicism
- Classical music was also dominated by the structures of the Austro-German tradition
- Romanticist music reacted against these structures in a fashion that parallels the connectionist revolution

Romanticism

- Romanticism arises in the years leading up to the 1789 French revolution, and persists until the end of the 19th century
- Romanticism was a reaction against the reason and rationality that characterized the Enlightenment that preceded it
- Romanticism emphasized the individual, the irrational, and the imaginative.
- Arguably music provided Romanticism's greatest expression (Einstein, 1947; Plantinga, 1984), because music expressed mystical and imaginative ideas that could not be captured by language
- Romantic music expressed intensity of feeling, it communicated the sublime. "It was a retrogression to the primitive relationship that man had had to music – to the mysterious, the exciting, the magical" (Einstein, 1947, p. 8)

Romanticism In Music

- Romantic music exhibits "a preference for the original rather than the normative, a pursuit of unique effects and extremes of expressiveness, the mobilization to that end of an enriched harmonic vocabulary, striking new figurations, textures, and tone colors" (Plantinga, 1984, p. 21)
- Nature was a common inspiration. The mountains and chasms of the Alps opposed the Enlightenment's view that the world was ordered and structured
- Romanticist composers include Schubert, Mendelssohn, Schumann, Chopin, Berlioz, Liszt, Wagner, and Brahms

Franz Liszt

Frederick Chopin
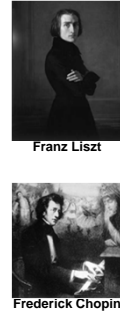
The Imaginary, The Sublime

- Musical Romanticism took great pains to convey the imaginary or the indescribable (Whittall, 1987)
- Consider Schumann's piano work *Humoreske* (Rosen, 1995). It uses three staves: one for the right hand, one for the left, and a third – containing the melody! – which is not to be played at all!
- Though inaudible, the melody "is embodied in the upper and lower parts as a kind of after resonance – out of phase, delicate, and shadowy" (Rosen, 1995, p. 8). The effects of the melody emerge from playing the other parts

Connectionist Analogy

- In summary, one can create an interesting analogy between connectionism and romanticism in music. How does connectionist research on music reflect this analogy?

	Connectionist Cognitive Science	Romanticist Music
Against symbolic formalisms	Abandon explicit rules and symbols	Instrumental music abandons language
Focus on imaginary and sublime	Inspired by the (complex) brain	Inspired by (sublime) natural world
Individualism	Study individual networks	Rise of the virtuoso soloist
More individualism	Unfunded connectionist scientist	The unappreciated artists
Preserve some of the old	Representations, disembodied	Symphonic form

Connectionist Genre Classification

- **Humans can classify short musical selections into different genres or styles within a quarter of a second, hard to model classically:**
  - **"It is not likely that musical styles can be isolated successfully by simple heuristics and introspection, nor can they be readily modeled as a rule-solving problem" (Loy, 1991, p. 31)**
- **However, many different ANNs have been developed to classify music using categories that seem to defy precise, formal definitions**
  - **Classify early works of Mozart**
  - **Classify different genres of western music**
  - **Predict "hit potential"**
  - **And many other examples**

Robert Gjerdingen

Chris Monterola

Connectionist Composition

- **Musical composition seems to need informal creativity**
  - **"The fact that even mature theories of music are informal is strong evidence that the performer, the listener, and the composer do not operate principally as rule-based problem solvers" (Loy, 1991, p. 31)**
- **ANNs are successful composers of new music**
  - **compose single-voiced melodies on the basis of learned musical structure**
  - **compose harmonized melodies or multiple voiced pieces**
  - **learn jazz melodies and harmonies, and then generate new melodies when presented novel harmonies**
  - **Learn stylistic, melodic, and acoustic constraints and then predict the next note in a new composition**
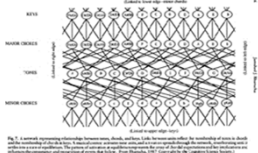
Gareth Loy

The Unsupervised Sublime

- **If connectionism is to capture aspects of music that cannot be formalized, then traditional learning techniques won't work**
- **The sublime can't be captured by supervised learning!**
- **Musical connectionists have a strong preference for unsupervised ANNs!!**

Jamshed Bharucha

The Musical Brain

- **In concert with connectionist studies of music is a growing literature about the cognitive neuroscience of music**
  - **Evidence about musical modularity**
  - **Double dissociation between language and music after brain injury**
  - **Genetic amusia**
- **Brain imaging studies**
- **Biological basis of music suggests it is not "brain candy", but is a complex system built on top of auditory processing**
  - **Not a simple or single module!**
  - **"The evidence of brain imaging studies has demonstrated that music shares basic brain circuitry with other types of complex sound, and no single brain area can be regarded as exclusively dedicated to music" (Warren, 2008, p. 34)**

Modern Music

- **20th century classical music also reacted against Austro-German traditions**
  - **"'Is it not our duty', he [Debussy] asked, 'to find a symphonic means to express our time, one that evokes the progress, the daring and the victories of modern days? The century of the aeroplane deserves its music'" (Griffiths, 1994)**
- **Modern music abandons tonality, musical logicism, central control of conductor and score, and disembodiment from performers and audience**
- **It reacts against classical music in a fashion analogous to the embodied reaction against classical cognitive science**
  - **"Debussy had opened the paths of modern music -- the abandonment of traditional tonality, the development of new rhythmic complexity, the recognition of color as an essential, the creation of a quite new form for each work, the exploration of deeper mental processes" (Griffiths, 1994)**

Claude Debussy

Paul Griffiths

From Tonality To Dodecaphony

- **Tonality is a key structural property of classical music, and is achieved by using particular subsets of the chromatic scale**
- **Schoenberg invented the 12-tone method to remove tonality from compositions**
- **The first example of a dodecaphonic composition was Schoenberg's 1923 *Suite for Piano, Op. 25***
- **Dodecaphony was later applied to other aspects of music in the serialism of Messaien, Boulez and Stockhausen**

Arnold Schoenberg

Piano Keys With Note Name	A	A#	B	C	C#	D	D#	E	F	F#	G	G#	A
A Major Scale	✓		✓		✓	✓		✓		✓		✓	✓
A Minor Scale	✓		✓	✓		✓		✓	✓		✓		✓

Table 2-2. The top row illustrates keys (white and black) on a piano from one A to the A an octave higher. The last two rows provide the subsets of notes that define A-major and A-minor scales; checkmarks are used to indicate which notes are included in a scale.

Removing The Composer's Control

- **Modern music also moved to remove the central control of the composer**
- **John Cage frequently relied on chance operations to compose**
  - **"When silence, generally speaking, is not in evidence, the will of the composer is. Inherent silence is equivalent to denial of the will" (Cage, 1961)**
- **These operations worked because of careful choice of "building blocks"**
  - **"In the *Music of Changes* the effect of the chance operations on the structure (making very apparent its anachronistic character) was balanced by a control of the materials" (Cage, 1961)**

JOHN CAGE
4' 33"
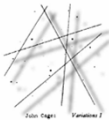
Minimalism and Emergence

- **Minimalists used simple, repetitive sound segments to induce auditory illusions**
  - **"The mind is mesmerized by repetition, put into such a state that small motifs can leap out of the music with a distinctness quite unrelated to their acoustic dominance" (Griffiths, 1994)**
- **Early minimalist discoveries were made from tape compositions such as Reich's *It's Gonna Rain***
  - **"In the process of trying to line up two identical tape loops in some particular relationship, I discovered that the most interesting music of all was made by simply lining the loops up in unison, and letting them slowly shift out of phase with each other" (Reich, 2002)**

La Monte Young

REICH

A Minimalist Score

- **Terry Riley's *in C* moved minimalist music into the traditional format of a musical score – note the return to tonality!**
- **However, *in C* did not rely upon central control**
- **Instead, the musicians interacted with the score stigmergically**
  - **Riley notes "one of the joys of *In C* is the interaction of the players in polyrhythmic combinations that spontaneously arise between patterns. Some quite fantastic shapes will arise and disintegrate as the group moves through the piece."**
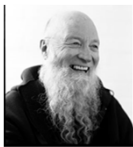
Terry Riley

Embodied Analogy

- **In summary, one can create an interesting analogy between embodied cognitive science and modern music. How does embodied research on music reflect this analogy?**

	Embodied Cognitive Science	Modern Music
Against central control	Stigmergy	Musical stigmergy
Focus on emergence	Swarm intelligence	Emergent musical phenomena
Against solipsism	Focus on worldly interactions	World and audience contribute
Synthetic emphasis	Forward engineering	Combine primitive musical elements
Importance of world	Situation and embodiment	Music as action and interaction

Embodiment And Music

- **According to the embodied view , the purpose of music is not to acquire abstract or affective content, but to instead to directly, interactively, and physically experience music**
- **"People try to be involved with music because this involvement permits an experience of behavioral resonance with physical energy" (Leman, 2008, p. 4)**
- **Hanslick (1854/1957, p. 48) argued that "the essence of music is sound and motion"**
- **What are the implications of this view of music?**
- **Perhaps the purpose of music involves engaging action, as well as human mirror neurons**

Marc Leman

Eduard Hanslick

Discovering Mirror Neurons

- **Fadiga, Fogassi, Gallese, and Rizzolatti were studying the brain's motor cortex – particularly area F5, associated with hand and mouth movements**
  - **"Then we began to notice something strange: when one of us grasped a piece of food, the monkeys' neurons would fire in the same way as when the monkeys themselves grasped the food" (Rizzolatti, 2006, p. 56)**
- **These have become known as mirror neurons**
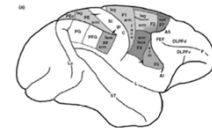
**Macaque monkey brain**

Luciano Fadiga

Mirror Neurons For Grasping

- **A mirror neuron for grasping fires when the monkey grasps a raisin from the tray (right image)**
- **The neuron also fires when the monkey observes the experimenter perform a similar grasping motion (left image)**
  - **The mirror neuron does not fire for an irregular grasp – the experimenter picking up a raisin with pliers**
  - **Some mirror neurons respond to placing actions (experimenter places target on a tray), and not to grasping actions**
  - **The mirror neuron fires when the monkey watches a sequence of movements intended to grasp a target, but not when the same movement is performed in the absence of a target**
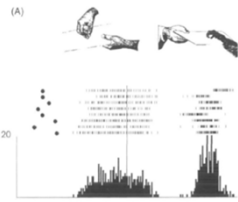

Human Mirror Neurons?

- **Do humans have mirror neurons?**
- **Various brain-imaging techniques reveal that observation of action causes brain activity that seems very similar to the monkey mirror system!**
- **Figure A shows activity when an object-less grasp is observed, while Figure B shows the increase of activity when the same grasp is observed directed towards an object (Buccino et al., 2001)**
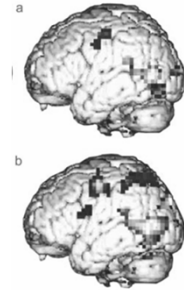
Mirroring Emotional Reactions

- **There is evidence that the human mirror system processes other stimuli that are more social in nature. The insula may be involved in the processing of negative affect!**
  - **Wicker et al. (2003) had subjects observe movies of actors sniffing the contents of a glass, and being disgusted, pleased, or neutral about the results**
  - **They then performed fMRIs on subjects who observed these movies**
  - **When subjects experienced disgust or pleasure, particular brain regions – the anterior insula, and to a lesser extent the anterior cingulate gyrus – were activated**
  - **When the same subjects observed the disgust or pleasure movies, the same areas activated – a mirror system for affect!**
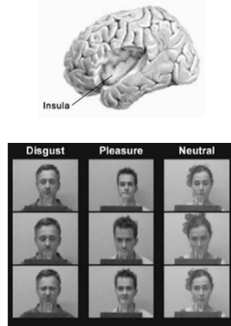

Mirroring And Music

- **If music involves communicating action and emotion, then it should stimulate the mirror system**
- **Vines et al. find that the experience of a musical performance is different when it is seen and heard, when compared to when it is simply heard**
  - **"The auditory and visual channels mutually enhance one another to convey content, and … an emergent quality exists when a musician is both seen and heard" (Vines et al., 2006, p. 108)**
  - **"The visual component of musical performance makes a unique contribution to the communication of emotion from performer to audience. Seeing a musician can augment, complement, and interact with the sound to modify the overall experience of music" (Vines et al., 2011, p. 168)**

Bradley Vines

Classical/Connectionist Hybrids

- **There are so many ill-defined notions concerning music – whether it communicates meaning vs. emotion, is formal or informal – that it presents the opportunity for hybrid theories**
- **For example, interpreting the internal structure of connectionist networks trained to perform musical judgments can reveal new kinds of musical representations**
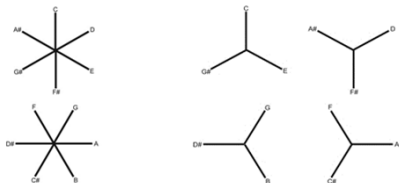
Connectionist/Embodied Hybrids

- **For a string instrument each note in a composition can be played by pressing different strings in different locations, and each location can be pressed by a different finger**
- **The choice of string, location, and finger is usually not specified in the composition; a performer must explore a variety of possible fingerings for playing a particular piece**
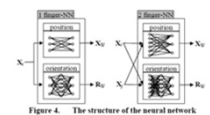- **Networks have been designed to suggest optimal fingering under various various constraints on fingering**