_____ _____

Name *Date*

FINAL EXAMINATION

MUSIC MIND & BRAIN

MUSIC INDUSTRY 103
UCLA HERB ALPERT SCHOOL OF MUSIC
2013-2014 ACADEMIC YEAR, SPRING QUARTER

Professor: Mark Tramo MD PhD

DUE WEDNESDAY JUNE 11, 2014
before 11:59 P.M.

Please
1. Fill in your name and the date above.
2. Complete the exam below without deleting any of the questions.
3. Save as a .DOC or .RTF file using a filename that includes your SURNAME.
4. Email to [redacted] by due date/time.

I. Conceptual & Methodological Approaches to Understanding Mind-Brain Relationships

1. In class, we discussed several concepts that form the foundation of modern scientific inquiry and guide experimental approaches to research on mind-brain correlates.

Write the letter of the concept on the line preceding the corresponding paragraph. Use each letter once.

A. Verificationism
B. Falsificationism
C. Existence Proof
D. Neuroanatomically-Dissociable Psychological Functions

_____ Introspection is not an acceptable scientific method for answering questions about how the brain perceives, performs, remembers, feels, and creates music. Nor are anecdotes an acceptable means of understanding the potential health benefits of "music therapy". One must formulate *testable hypotheses* whose truth value can be tested via well-controlled experiments. Propositions whose truth value cannot be tested through empirical observation lie outside the realm of science. (4 pts)

_____ Case SC, a Tony Award-winning musical director, suffered damage the Orbitofrontal Gyri in the Left and Right Frontal Lobes due to a Stroke. Subsequently, he couldn't control his emotional and visceral responses to music, especially his lifelong favorites, like Puccini's *Madame Butterfly*. Conclusion: one's ability to control emotional and visceral responses to music *can* be lost following lesions of the Left and Right Orbitofrontal Gyri, but we don't know if that's true for most people, especially since SC had extraordinary talent in music. (4 pts)

_____ We really can't prove any hypothesis is true beyond doubt using scientific methods. What scientists *can* do is exclude what is *not* true. By ruling out hypotheses using rigorous empirical methods, scientists can refute or refine a theory, even if they can't prove beyond a doubt the theory is true. Scientific theories advance and evolve over time by this process. (4 pts)

_____ Carl Wernicke was a 19th century German neurologist who published the first cases of what he termed "Cortical Deafness" and "Sensory Aphasia". The latter term is now often referred to as "Wernicke's Aphasia". In right-handed patient populations with Left Hemisphere strokes involving posterior Auditory Association Cortex, speech comprehension is severely impaired (Sensory Aphasia) but speech production is normal or mildly impaired. This observation suggests that speech comprehension and speech production are governed by different mental operations housed in different brain regions. (4 pts)

2. In lectures and seminar presentations of professional journal publications, we discussed the handful of methods presently available to neuroscientists who want to study music cognition. Limitations in these methods inherently limit the questions neuroscientists can answer experimentally. For example, much is known about the gross-anatomy and gross-physiology of human auditory cortex but very little is known about its micro-physiology, which we infer from work in other animals, especially in the primate Genus *Macaca* (commonly called "macaques") of the primate Family *Cercopithecidae* (commonly called "Old World Monkeys").

Below is a list of methods used to study gross brain anatomy, pathology, physiology, and chemistry in humans and other animals. Write the letter of the method on the line preceding the corresponding description. Use each letter once.

A. MRI (a.k.a., anatomical MRI)
B. PET
C. MEG
D. fMRI

_____ Measures magnetic field potentials generated by millions of neurons in different regions of the brain with excellent temporal resolution and poor spatial resolution. Has been used to study expectancy generation, violation, and satisfaction during music listening (2 pts)

What does the abbreviation stand for? (2 pts)

_____

_____ Measures blood flow, glucose consumption, and/or oxygen consumption in the working brain using radioactive chemicals. Can also be used to estimate the binding radioactive ligands to neurotransmitter receptors (e.g., dopamine or opioid receptors). Spatial resolution is fair and temporal resolution is poor. Measurements are almost always averaged across subjects, whose brains are often warped to fit a standard, 3D brain template of a dead Frenchwoman's brain published by Talairach et al. (2 pts)

What does the abbreviation stand for? (2 pts)

_____

_____ Well-suited for studying brain anatomy and pathology (lesions) with superb spatial resolution. T1-weighted images can be used to measure the volume of the superior temporal gyrus in each hemisphere and test "bigger is better" hypotheses (e.g., the hypothesis that the posterior superior temporal gyrus in the left hemisphere is bigger in musicians with absolute pitch than in non-musicians). T2-weighted images are especially useful for identifying areas of the brain that are damaged by strokes and other diseases. Temporal resolution is nil, so it can't show the working brain. (2 pts)

What does the abbreviation stand for? (2 pts)

_____

_____ Measures hemodynamic activity [e.g., blood oxygen-level dependent (BOLD) changes – an index of brain oxygen consumption]. Does not use radioactive chemicals. Spatial resolution and temporal resolution are good but not great. In most experiments, measurements are averaged across subjects, whose brains are warped to fit a standard, 3D brain template of a dead Frenchwoman's brain published by Talairach et al. (2 pts).

What does the abbreviation stand for? (2 pts)

_____

3. Methods used to study the brain vary with respect to their spatial resolution and temporal resolution. If a neuroscientist is interested in neuroanatomical detail, then using "high-def" spatial resolution is important. If a neuroscientist is interested in how neuronal activity changes rapidly over time, then using methods with high temporal resolution is important.

a. True or false? (put a "T" or "F" on the line before each statement (4 pts)

____ A spatial resolution of 1 cm is better than a spatial resolution of 10 mm
____ A spatial resolution of 1 mm is better than a spatial resolution of 1 cm
____ A temporal resolution of 1 millisecond is better than a temporal resolution of 500 microseconds
____ A temporal resolution of 100 microseconds is better than a temporal resolution of 100 milliseconds

b. Rank the following methods' spatial resolution from best (1) to worst (4). Write the rank on the line to the left of the method. (4 pts)

____ anatomical MRI
____ EEG
____ fMRI
____ PET

c. Rank the following methods' temporal resolution from best (1) to worst (4). Write the rank on the line to the left of the method. (4 pts)

____ anatomical MRI
____ EEG
____ fMRI
____ PET

4. Below is a list of methods used in psychophysical experiments designed to measure perceptual acuity. Write the letter of the method on the line next to the description it matches. Use each letter once.

A. Method of Constant Stimuli
B. Method of Adjustment
C. Adaptive Method

_____ Violinists, guitarists and other string players use this method to tune each string on their instruments. (2 pts)

_____ Stimulus variables are "canned" and the results depend on how you set those variables before doing the test (including this final exam). Not well-suited to defining psychophysical thresholds [e.g., the difference threshold, a.k.a. difference limen (DL) or just noticeable difference (JND) for pitch discrimination]. (2 pts)

_____ Stimulus variables change depending on how well the subject does. The GREs use this method. Well-suited to measuring JNDs. (2 pts)

II. Pictures of Sound & the Psychoacoustics of Music

5. To understand neuroscientific approaches to music-related functions, especially those related to acoustic feature extraction and auditory percept formation, it is helpful to picture sounds graphically in two dimensions (e.g., acoustic waveforms; amplitude spectra) and three dimensions (e.g., spectrograms) and to learn the names of auditory objects and features used in the "language games" played by musicians, acousticians, psychologists, and neuroscientists.

In class, we used digital sound recording, editing, and analysis software (Audacity®, Amadeus®) to look at acoustic waveforms, amplitude spectra, and spectrograms. Write the letter of the type of sound-picture on the line preceding the corresponding description.

A. Acoustic Waveform
B. Amplitude Spectrum (a.k.a., Power Spectrum, Magnitude Spectrum)
C. Spectrogram (a.k.a. Voiceprint)

_____ A picture of sound in the Time Domain (2 pts)

_____ A picture of sound in the Spectral Domain (2 pts)

_____ A picture of sound in both the Time & Spectral Domains (2 pts)

_____ x axis = frequency (usually Hz); y axis = amplitude of sound pressure fluctuations at the corresponding frequency (usually dB SPL re: 20 microPascals). (2 pts)

_____ x axis = time (usually milliseconds); y axis = frequency of sound pressure fluctuations at the corresponding time (in Hz); z axis (e.g., color) = amplitude of sound pressure fluctuations at the corresponding time and frequency (usually dB SPL re: 20 microPascals). (2 pts)

_____ x axis = time (usually milliseconds); y axis = amplitude of sound pressure fluctuations at the corresponding time (usually dB SPL re: 20 microPascals). (2 pts)

6. How is the period (T) of a pure-tone (a.k.a. sinusoidal-tone) related to the frequency (F) of sound wave vibrations? Put an X on the line preceding the correct answer. (2 pts)

_____ $T = 2 \times F$

_____ $T = F/2$

_____ $T = F^2$

_____ $T = 1/F$

_____ none of the above

7. Pure-tones really don't exist in the natural sound environment – one needs a digital or analog device to generate them. Even then, loudspeakers and our ears "distort" pure-tones – i.e., introduce other frequencies - especially at high amplitudes. String instruments like the guitar, violin, and piano produce complex-tones that contain multiple frequencies, including a strong fundamental frequency (F0) that gives rise to a strong pitch percept. Before classical music concerts, we often hear violinists and string players tuning their instruments to the pitch A4.

What is the fundamental frequency (F0) (in Hz) of string vibrations corresponding to the pitch A4?
_____ (2 pts)

What is the fundamental period (in milliseconds) of A4?
_____ (2 pts)

8. What are the frequencies of harmonics 4, 5, and 6 of a harmonic series with F0 at C5? (Hint: Calculate F0 of C5 from the frequency of A4, then calculate the frequencies of the harmonics from F0 of C5.)

_____ (4 pts)

8. Psychoacoustics is a discipline of Psychology that is concerned with the relationships between physical (acoustical) features of sound and perceptual (psychological, mental) attributes of sound. Write the letter of the *acoustical feature* on the line preceding the *musical percept* it is most closely related to. Use each letter once.

A. Sound Pressure Amplitude (related to Intensity, Power, Sound Pressure Level)
B. Frequency
C. Duration

_____ Pitch (2 pts)

_____ Duration (2 pts)

_____ Loudness (2 pts)

9. Which has the highest pitch? (Write an "X" on the line in front of the correct answer; 4 pts)

_____ a 440 Hz pure-tone

_____ a harmonic tone with a fundamental frequency at 660 Hz

_____ a harmonic tone with a "missing" fundamental frequency at 880 Hz

10. Why do most musical cultures have scales anchored by 7 or fewer pitches per octave when the human auditory system can resolve dozens of pitches per octave? Why not have 50 pitches per octave instead of 7? Isn't more better? Please limit your answer to 140 characters or less. (4 pts)

_____

_____

III. Neuroanatomy and Neurophysiology of Music Cognition

11. Do you hear yourself reading this sentence? There are no sound waves corresponding to what you "heard". Even when there are sound waves evoking the pre-conscious formation of auditory percepts, there are no sound waves in your brain. Your auditory nervous system

"represents" the physical and perceptual features of sound using three basic types of neural codes.

What are the three basic types of neural codes the brain can use to represent music, speech, and environmental sounds? Note: testing specific hypotheses about which of these codes, and how many, are used for pitch perception, speech recognition, and other auditory functions in our natural sound environment is an active area of research in Neuroscience.

_____ (6 pts)

12. Modality-specific neurons increase or decrease their activity *only* when *one type* of peripheral neuron (auditory, visual, tactile, motor, etc.) is active. In the cerebral cortex, the 2-3 mm-thick "brain peel" that covers the surface of the cerebral hemispheres, modality-specific neurons are not scattered throughout the 2000 cm^2 expanse of the cortex but are localized in the same region of cortex, sometimes within a specific gyrus.

The surface of the cortex has hills and valleys - the extrasulcal and intrasulcal portions, respectively, of the cortical convolutions. The cortical surface can be subdivided into gross anatomical structures: each hemisphere is divided into lobes, and each lobe is divided into lobules, gyri, and other sub-structures. The boundaries between gyri are sometimes well-defined and sometimes not.

Which of the following gyri of the cerebral cortex contain modality-specific neurons that increase or decrease their activity *only* when inner hair cells and Type I spiral ganglion cells in the cochlea are active? Put an "X" next to all that apply. (4 pts)

____ superior temporal gyrus

____ middle temporal gyrus

____ inferior temporal gyrus

____ pre-central gyrus

____ post-central gyrus

____ orbitofrontal gyrus

____ transverse gyrus of Heschl

13. We saw in the *Journal of Comparative Neurology* paper by Morel, Kaas, and colleagues that neurons in the auditory cortex field called "A1" are arranged according to their "Best Frequency (BF)". This orderly arrangement of neurons according to their BF is termed "Tonotopy" or, equivalently, "Cochleotopy". One way to define BF is to identify the pure-tone frequency that excites the neuron most at a given intensity (say, at 40 dB SPL). Excitation is indexed by measuring the number of action potentials (or "spikes") fired by the

neuron per second while the tone is on. This is an example of the brain using two of the above three candidate codes to represent frequency. Which two codes?

_____ (4 pts)

14. Auditory information presented to the right ear gets relayed to (Write an X on the line before the correct answer; 2 pts):

_____ the right auditory cortex ("ipsilaterally")

_____ the left auditory cortex ("contralaterally")

_____ both the left and right auditory cortices ("bilaterally")

15. Indicate below which gyrus of the cerebral cortex houses Primary Auditory Cortex by typing "A1" on the line in front of the gyrus. Then indicate below which gyrus houses almost all of Auditory Association Cortex by typing "AA" on the line in front of that gyrus. (4 pts).

_____ transverse gyrus of Heschl

_____ parahippocampal gyrus

_____ superior frontal gyrus

_____ superior temporal gyrus

_____ cingulate gyrus

_____ orbitofrontal gyrus

16. Write the letter of the auditory perceptual deficit next to the lesion that causes it. (4 pts)

A. Inability to judge with high acuity whether two pure-tones have the "same" pitch or a "different" pitch.

B. Inability to judge with high acuity whether the second of two pure-tones is "higher" or "lower" in pitch than the first.

C. Both A and B

D. Neither A nor B

_____ complete bilateral lesions of the transverse gyri of Heschl and partial bilateral lesions of the superior temporal gyrus

_____ unilateral lesions of the right transverse gyrus of Heschl and right anterior superior temporal gyrus

17. Recognition memory for the melodies of songs is impaired following lesions of which of the following brain structures? Check all that apply. (4 pts)

_____ right anterior temporal lobe

_____ right anterior frontal lobe

_____ left anterior temporal lobe

_____ left anterior frontal lobe

18. Recognition memory for lyrics of songs is impaired following lesions of which of the following brain structures? Check all that apply. (4 pts)

_____ right anterior temporal lobe

_____ right anterior frontal lobe

_____ left anterior temporal lobe

_____ left anterior frontal lobe

19. The Corpus Callosum is a huge bundle of axons (over 100 million) that connects: (Write an X next to your answer; 2 pts):

_____ the Temporal Lobe and Frontal Lobe

_____ the Temporal Lobe and Parietal Lobe

_____ the Cerebral Hemispheres and the Brainstem

_____ the Left and Right Cerebral Hemispheres.

20. Which hemisphere of split-brain patients JW and VP had a higher response accuracy when it judged individual musical chords (major triads) that were "In-tune"? See Experiment 2 in the split-brain paper by Tramo and Bharucha. (4 pts)

_____ Left Hemisphere

_____ Right Hemisphere

21. The auditory neurophysiology literature is replete with papers describing neural correlates of one or more *physical* features of sound like frequency or intensity. Finding neural correlates of *perceptual* features that remain constant despite physical changes in the stimulus is more challenging.

In class, we covered two neural coding papers describing brain responses that depended on perceptual, not physical, features of the stimulus. In the paper by Bendor and Wang, we saw that the spike rate of A1 neurons in awake New World monkeys depended on the pitch of a harmonic-tone, even when the fundamental frequency of the tone was removed and the spectral energy distribution among harmonics was varied. In the paper by Iversen et al., we saw that MEG activity in a specific frequency band of "brain waves" followed beats embedded in a rhythm, even when the beat was missing (illusory or "imagined" beats). Which MEG frequency band(s) contained the neural representation of the imagined beat? (4 points)

____ alpha (8-12 Hz)
____ beta (13-30 Hz)
____ gamma (31-100 Hz)
____ theta (4-7 Hz)
____ delta (1-3 Hz)

22. In right-handers, the left cerebral hemisphere plays a critical role in the ability to articulate ideas and comprehend sentences.

True or false? – In right-handers, the right cerebral hemisphere is the "musical hemisphere" – i.e., it plays a critical role in all aspects of music perception and cognition. Put an "X" next to your answer. (4 pts)

_____ True

_____ False

23. Match the type knowledge with the corresponding example below. (4 pts)

A. Explicit knowledge
B. Implicit knowledge

____ Knowing that a IV chord often follows a I chord in popular rock, folk, and country music.

____ Knowing that Avogadro's number equals 6.02×10^{23}

24. The ability to name the pitch of any sound, termed "absolute pitch" or "perfect pitch", is in one sense a "talent" and in another sense a handicap inasmuch as musicians with absolute pitch find transposition from one key to another more difficult than those without AP. Neuroanatomists have measured the size of the superior surface of the superior temporal gyrus, the planum temporale, in musicians with absolute pitch. Put an "X" next to the line that describes the relative size of the left vs. right planum temporale in musicians with absolute pitch. (4 pts)

____ the left planum temporale is bigger than the right planum temporale in musicians with absolute pitch

____ the right planum temporale is bigger than the left planum temporale in musicians with absolute pitch

____ the left planum temporale is about the same size as the right planum temporale in musicians with absolute pitch

25. We looked at two experiments that sought neural correlates of musical creativity by measuring fMRI activity during keyboard improvisation. True or False? (4 pts)

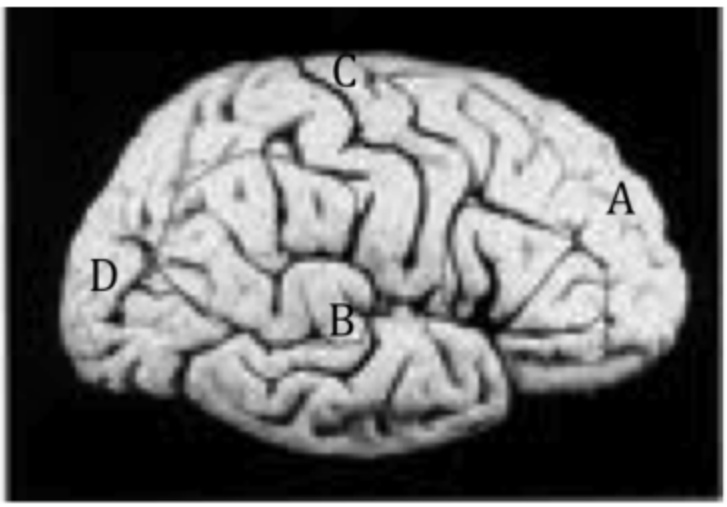
____ during improvisation, all of the cerebral cortex increases its activity

____ during improvisation, the right cerebral cortex works harder than the left cerebral cortex

____ during improvisation, the left cerebral cortex works harder than the right cerebral cortex

____ during improvisation, some areas in the left and right cerebral cortex symmetrically increase their activity while other areas in the left and right cerebral cortex symmetrically decrease their activity

26. Match the Music-Related Function to its *Anatomical* Location (see the *letter* on the Lateral View of the Right Hemisphere below) and its corresponding *Functional Subsystem of the Cerebral Cortex* (see the corresponding *Roman numeral* in the list below the brain). Write the letter/numeral on the line following the description. Use each letter and numeral once.



I. Modality-Specific System (Auditory)
II. Modality-Specific System (Motor/Somatosensory)
III. Modality-Specific System (Visual)
IV. Supra-Modal System (Future-Supramodal Subsystem)

Auditory Analysis & Representation (e.g., perception of melody, harmony, rhythm, timbre, voice):

Corresponding Anatomical Structure: Letter = _____. (4 pts)
Corresponding Functional Cortical Subsystem: Roman Numeral = _____. (4 pts)

Expectancy Generation, Violation, & Satisfaction (e.g., repetition, return, appoggiatura):

Corresponding Anatomical Structure: Letter = _____. (4 pts)
Corresponding Functional Cortical Subsystem: Roman Numeral = _____. (4 pts)

Visual Perception (e.g., stage lighting, scene design, facial expression, body language):

Corresponding Anatomical Structure: Letter = _____. (4 pts)
Corresponding Functional Cortical Subsystem: Roman Numeral = _____. (4 pts)

Kinetics & Kinesthetics (e.g., dancing, singing, foot-tapping – moving):
Corresponding Anatomical Structure: Letter = _____. (4 pts)
Corresponding Functional Cortical Subsystem: Roman Numeral = _____. (4 pts)

IV. Music, Health & Medicine

27. Put a "Y" next to health problems music might alleviate and an "N" next to those music would be unlikely to help. (4 pts)

____ Pain and stress during, before, and after medical procedures

____ Killing the bacterium (*Streptococcus pyogenes*) that causes "Strep throat"

____ Initiation and guidance of movement in patients with Parkinson Disease and related Movement Disorders

____ More rapid and complete recovery of the ability to speak after left hemisphere stroke by incorporating singing and other forms of Melodic Intonation Therapy into Speech Therapy