HOMEWORK DUE NOVEMBER 8, 2018 by 6PM

1. Thus far in our Harmony Seminar, lectures introduced basic concepts in Western Music Theory (e.g., scales and keys) and their acoustic correlates, particularly the relations among the fundamental frequencies (F0) of simultaneous notes - the two simultaneous notes in a "harmonic interval," and the three or more simultaneous notes in a musical chord (e.g., major triads). The papers presented thus far in class covered two important Psychology experiments in the subdisciplines called Psychoacoustics (a.k.a. Auditory Psychophysics) and Cognitive Psychology. Last week's homework questions brought us into the realm of neuroscience via experiments combining methods developed in the discipline of Neurology with those of Psychoacoustics and Cognitive Psychology. This coming week, we will look at an electrophysiological method – Event-Related Potentials (ERPs) - that allows us to probe with high temporal resolution the time course of cortical activity mediating the perceptual processing of chord sequences. These sequences of chords, arranged in orderly, non-random, repetitive, and rhythmic patterns, make up the harmonic progressions Professor Fink discussed – the various permutations of I, IV, and V sequences in rock'n'roll dance music like The Beatles' *Twist & Shout* and of I-IV-V-vi sequences in ballads like *This Boy* and *Let It Be*.

A major theme in cognitive neuroscience research is "hemispheric specialization and lateralization." We've known since the mid-19th century that, for almost all right-handed adults, our left and right cerebral hemispheres house different mental operations, such that the left hemisphere is "dominant" for all functions performed in the Verbal Domain and the right hemisphere is dominant for some functions performed in the Non-Verbal Domain. One way of getting at the question of left-right differences is to test each half-brain separately.

One of the members of Dartmouth College's Alpha Delta Phi "Animal House," Glendale's Mike Gazzaniga (known as "Giraffe" in the script and in real life), decided not to follow his father and brother to medical school but instead pursue a Ph.D. in Psychobiology with Roger Sperry at Cal Tech in the early 1960s. Soon after, a neurosurgeon at LA's White Memorial Hospital, Joe Bogen, demonstrated that some patients with Epilepsy whose life-threatening seizures could not be controlled by medications got a lot better after he cut the corpus callosum and disconnected their cerebral hemispheres. Having worked out the methodology in macaques, the Cal Tech graduate student began a series of ground-breaking experiments with "split-brain" patients. Hundreds of psychology experiments probing the separated hemispheres of "split-brain" patients followed over the next four decades, most notably by Mike at Dartmouth and Eran Zaidel and Dahlia Zaidel here at UCLA, who also did their Ph.D. work with Sperry at Cal Tech. While this method is properly classified as a lesion-effect method, it is unique in that one gets to test a *whole* half-brain with no lesions and all of its intra-hemispheric connections intact. In lesion-effect experiments with stroke patients and temporal lobectomy patients, there is always damage to neurons as well as their intra- and interhemispheric connections in at least one hemisphere.

In 1981, Sperry, partly for his split-brain work, was awarded the Nobel Prize in Physiology or Medicine alongside David Hubel and Torsten Wiesel for their contributions to our understanding of how the brain works. I can say first-hand that David considered the first split-brain papers by Gazzaniga and Sperry in the journal *Brain* among the best-written, fun reads in the history of Neuroscience. I've attached the one on language in the Week 4 (Harmony) link on CCLE.

The following homework questions pertain to music experiments on harmony perception my colleague Jamshed Bharucha and I did with two of Mike's split-brain patients (*Neuropsychologia* 1991 – see CCLE Week 5 link) after he moved our lab from the tony Upper East Side of Manhattan, where we were working at Cornell Medical College, to the frigid, dark wilderness of Hanover, New Hampshire, the home of Dartmouth College and Medical School.

Figure 2 in Tramo & Bharucha schematizes the methodological "trick" that allowed us to test each half-brain separately. In previous years, John Sidtis tried pitch experiments with Mike's patients using the "dichotic listening method" – the most popular method used in music psychology and neuropsychology experiments in the 1970s and 1980s. Different stimuli are presented simultaneously to each ear, then a question is asked about them. The method went extinct in the 1990s because it doesn't work reliably and new methods became available (MRI, PET, fMRI). After all, each ear is connected to *both* cerebral hemispheres – not only via the corpus callosum, but also via multiple "commissures" in the brainstem. So cutting the corpus callosum still leaves plenty of cables carrying auditory information from right to left and vice versa intact. The situation is different for the visual system because of the way the retina of the eye is connected to primary visual cortex in the left and right occipital lobes: if we have a split-brain patient fixate a dot in the middle of the visual field then flash a picture far enough to the left or right faster than the eye can move, only one hemisphere – the one opposite to the side of the stimulus – sees the picture. So we can just play the sounds over loudspeakers to both hemispheres but give the "answer sheet" to only one hemisphere. (Your neural representation of the lateralized picture would go to one hemisphere initially, but it doesn't get trapped there because it quickly crosses over to the other hemisphere via the splenium of your intact corpus callosum.)

Table 1 shows the results of an experiment on consonance perception by the half-brains of patients J.W. and V.P. The stimuli were isolated musical chords. Half the chords were major triads; the other half were major triads whose fifths were mistuned (flattened) by a fraction of a semitone. We used a one-interval two-alternative forced-choice task and the method of constant stimuli. The task required each half-brain to judge whether the chord sounded in-tune or out-of-tune. On each experimental trial, both hemispheres heard the stimulus via both ears, then the response choices were presented visually to only one hemisphere by lateralizing the choices to the left or right visual field. Both verbal and non-verbal response choices were presented next to each other: "in-tune" with a smiley face above or below "out-of-tune" with a sad face. The hand controlled by the hemisphere that saw the picture pointed at the hemisphere's response. (The right hemisphere doesn't talk so it can't just say its response – it has to communicate its answers some other way – e.g., pointing to response choices presented visually.)

In a two-alternative forced-choice task, chance performance corresponds to a response accuracy of: (Put an X on the line next to the correct answer) (2 points)

_____ 10%

_____ 25%

__X__ 50%

_____ 75%

2. Place the letter corresponding to the correct answer on the line next to each question about Table 1:

A. Left Hemisphere
B. Right Hemisphere
C. Both Hemispheres
D. Neither Hemisphere

__B__ for both patients J.W. and V.P., overall response accuracy was significantly above chance (i.e., the *t* statistic corresponds to a two-tailed *p* value less than or equal to 0.05).
(4 points)

_A__ for both patients J.W. and V.P., overall response accuracy was not significantly above chance (i.e., the t statistic corresponds to a two-tailed *p* value greater than 0.05) (4 points)

__B__ for both patients J.W. and V.P., response accuracy for in-tune targets in this hemisphere was better than that in the opposite hemisphere; however, the difference was statistically significant only for V.P.
(2 points)

__A__ for J.W., this hemisphere was "biased" to hear chords as out-of-tune. (2 points)

3. In one of our introductory lectures, we discussed the phenomenon of "priming." In class, I asked you to decide whether a string of letters briefly flashed onto the projector screen made up a word. This is known as a "lexical decision task." In experiments with young adult populations, subjects quickly and correctly judge the letter string NURSE. But if DOCTOR is flashed before NURSE is flashed, subjects are even faster at correctly judging NURSE to be a word. This is an example of a "priming effect," in this case "lexical priming." If WORLD precedes NURSE, there is no priming effect – priming depends on the semantic relatedness of the first chord (DOCTOR vs. WORLD) to the following target chord (NURSE).

When he was a Psychology graduate student at Harvard, Jamshed, a violinist, wanted to discover a priming effect in the music domain. His professor was one of Roger Shepard's former graduate students at Stanford, Carol Krumhansl, also a violinist. Carol, now a long-time Cornell professor, is one of the first experimental cognitive psychologists to work on music and has been a leader in the field for decades – I brought her book *Cognitive Foundations of Musical Pitch* to class, and one of her papers is among the Emotion & Meaning PDFs uploaded to Week 6 in CCLE.

Jamshed eventually succeeded in discovering a type of musical priming. The results he obtained with Dartmouth undergraduates are shown in the left-most group of four bars ("Normals" on the x axis) in Figure 3 of our *Neuropsychologia* paper. The task is similar to the one above: a one-interval, two-alternative forced-choice task using the method of constant stimuli. Half the target stimuli are in-tune major triads, the other half out-of-tune triads with flattened fifths. However, in this priming task, the target chord is preceded by an in-tune major triad, the "prime." In half the trials, the prime chord and target chord are harmonically related – they belong to the same musical key; in the other half, they are from different keys and are harmonically unrelated.

Below, place a "T" on the line next to the proposition if it is true and an "F" if it is false. (Just visually analyze Figure 3 – no need to get into all the statistics in the text of the Results section.)

__T__ Normals' response accuracy was higher when an in-tune target chord was preceded by a chord from a related key than when it was preceded by a chord from an unrelated key (2 points)

__T__ For each of J.W.'s hemispheres, response accuracy for in-tune targets was higher when the target was preceded by a chord from a related key than when it was preceded by a chord from an unrelated key, but the overall accuracy of J.W.'s left hemisphere for in-tune targets was below chance (2 points)

__T__ For V.P.'s right hemisphere, response accuracy for in-tune targets was higher when the target was preceded by a chord from a related key than when it was preceded by a chord from an unrelated key, but there was no evidence of this priming effect for her left hemisphere. Moreover, for in-tune targets, left hemisphere performance was below chance (2 points)

__T__ The pattern of performance by the right half-brains of J.W. and V.P. was a lot like the whole-brains of Dartmouth undergraduates. (2 points)

__F__ The results of split-brain experiments suggest that auditory functions mediating harmony perception are lateralized to the left cerebral hemisphere. (4 points)

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