Book Reviews

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What Are Musical Paradox and Illusion?[1]

Musical Illusions and Paradoxes
By Diana Deutsch. La Jolla, CA: Philomel, 1995. 23-track CD recording, $14.95.

Phantom Words and Other Curiosities
By Diana Deutsch. La Jolla, CA: Philomel, 2003. 26-track CD recording, $14.95.

In the early documentation of a now-famous series of experiments, Diana Deutsch (1986) described an acoustic circumstance in which a particular pitch interval, between successive tones in a particular artificial timbre, produces perceptual results that we might not expect: When the pair of notes was transposed, the interval seemed to change direction. Furthermore, although individuals' changing reports were consistent as functions of pitch transposition, the pattern of change varied from listener to listener.

This was a remarkable finding, but nonmusicians do not always comprehend its implications. To make the mystery more accessible, Deutsch followed with a metaphor that appeals to vision rather than hearing.

> Melodies are like visual shapes. . . . The notion that a melodic pattern might be perceived as radically different under transposition appears as paradoxical as the notion that a visual shape might undergo a metamorphosis through being shifted to a different location in space. (Deutsch, 1986, p. 275)

Indeed, the idea that any series of pitches would be unrecognizable under transposition is a radical departure from normal assumptions about the workings of pitch (both in music literature and in the brain). Any musician, *knowing* she had experienced an accurate transposition—that is, one melody in two different keys—without also maintaining a basic sense of its identity, might describe the experience as some essential failure of attention, or of the senses: an illusion. Another might call it a contradiction of otherwise stable doctrines: a paradox. Nevertheless, the idea that we can compare musical experiences to these purely sensory and rational notions of illusion and paradox is itself a remarkable and bold conversation-starter. When common sense leads us to conclusions that we later discover are unreal (illusions) or impossible (paradoxes), we usually experience a moment of doubt in relation to the process that led us there. "I cannot have sensed that," we reason when a ventriloquist's voice apparently comes from a wooden mouth[2] or when our eyes complete the circular path of M. C. Escher's endless staircase[3] drawing. Of the Barber's Paradox[4] we say, "Such a barber does not exist." We can produce in visual or mental space various perplexities of objects, or stimuli that seem to reflect a physical or conceptual impossibility, precisely because we exist in such spaces, and we have time to confirm or refute their arrangements. In pure sound, on the other hand, we tend to imagine varying degrees of imperfect understanding. Most hearing is a fleeting assessment of physical reality; for verification of the ears' receptions, we call on other senses.

Likewise, normal musical listening involves judgments of pleasure and plausibility, never quite in the domain of the possible or impossible. The musical impossibility just described seems to depend not only on hearing music but on advance knowledge, or trust, about what the information *is*. Without such help, we hear either one thing (an identity-bearing transposition) or another (a pair of contrasting melodic motions), and although one of those reports, if they describe the same affair, must be a mistake, a mistake without correction does not lead us to feel that anything is amiss. Can we have this paradox, then, as a musical experience?

In the same way, the idea of a musical illusion seems to require advance knowledge of what a sound *is* as a basis for comparison to what it *sounds like,* and for those of us who are not familiar with the work of acousticians, that distinction seems to be a paradox all its own.[5] In a visual illusion,[6] the being of the image is normally compared to a real thing that it suggests, and the two are found not to have much similarity of physical existence. (Think of lines converging upward toward the center of a piece of paper, compared with a pair of parallel lines—white lines on a freeway perhaps—extending and vanishing into the distance). To what being should we compare a melody in order that we would find it misleading?[7] Even if music and artificial sound sometimes are representational, reliably conveying basic objects, ideas, or mental states, they cannot really convey the absence of them. Nor can they reliably specify their relationships to one another, so that we might consider those relationships, such as those between a barber and his customers or between three-dimensional and two-dimensional space, either improbable or illusory.

It is because of problems like these that, over millennia of philosophers', poets', and artists' fascinations with illusion and paradox, few composers have been recognized in the conversation.[8] In two CDs published by Diana Deutsch in the last 12 years, however, music has defied this author's intuitions and crashed the scene. In the early 1990s, Deutsch produced *Musical Illusions and Paradoxes* from various ideas central to her research over the previous two decades. On it are seven engrossing compositions (although she does not refer to them as art) that demonstrate, with commentary and instructions, auditory phenomena that appear to exist acoustically in ways that they do not. More recently, Deutsch released a follow-up disk, *Phantom Words and Other Curiosities,* which explores the features of three more auditory illusions, along with a demonstration of some illusion-like peculiarities in our memory for pitches. Most of these examples are of recorded speech or of simple combinations of pure sinusoid tones; the craft is in their rhythmic distribution, their stereo distribution, or the balance of their intensities. The perceptual result of each composition, though, usually is something decidedly less, more, or entirely other than the sum of the stuff of which it is made.

In what follows I will briefly summarize the stimuli and likely percepts of

Deutsch's demonstrations and then focus more thoroughly on two of Deutsch's supporting categories of research. Those examples—the octave illusion and the tritone paradox—compel questions about what cognitive mechanisms are responsible for the sometimes tentative orderliness of pitch, time, timbre, and musical shape. In these areas, Deutsch's work connects the compositional concerns of her CDs with broader issues in the perception of musical structure.

Overview of the disks

Musical Illusions and Paradoxes is an album of examples that throw into disarray our normal perceptual organization of proximity and distance in musical space. Where one parameter of difference should separate sounds into distinctive groups, another contradicts the segregation with an "aggregating" proximity. Sometimes these contradictions lead not merely to an ambivalence or plurality of interpretations but to irrational percepts that suggest an entirely different stimulus. For each example, Deutsch has recorded some practical commentary in her own voice, with a pleasing hint of drama reminiscent of mystery or science fiction. Her careful and clear explanations are also printed in the CD jacket, and they are obviously an important educational component of the whole project. The differences between what the sounds are (or "should be") and what they "sound like" can be reconciled only with a deeper appreciation of psychoacoustics, and that is this album's finest contribution.

The octave illusion is a steadily pulsing alternation between pairs of notes that are an octave apart, in opposite ears; the position of each tone alternates between left and right channels (see Figure 2 below, where the illusion and its implications are discussed in more detail). Despite its simplicity, listeners hear a variety of other phenomena, the most common being one in which, among other problems, the lower pitch appears repeatedly in the wrong ear at the wrong time.

"High–low" replicates the octave illusion with words, in a stimulus that similarly projects the pair of words *high* and *low* at high and low fundamental frequencies. The effects of the illusion are similar in that we tend to localize the words contrary to their actual stereo arrangement. In addition, the words' juxtapositions (either apparent or real) generate phoneme groupings that lead to the perception of other syllables and words. (This observation led Deutsch to a more elaborate set of compositions on her next CD.)

The scale illusion is a pair of disjunct diatonic melodies, one in each ear, that aggregate to form simultaneous ascending and descending scales. If our perceptions tend to privilege connections between notes that are close to one another in pitch, they will reflect the relative continuity of the scales' stepwise motions rather than accurately report one jagged pitch series spatially segregated from another. That same preference for pitch continuity also disrupts the flow of individual scales (crossing after the fourth note) and suggests a pair of less familiar syncline/anticline forms (Figure 1). The doctrine of pitch proximity as a basis for group organization trumps both the stimulus' interaural difference cues and any pattern recognition cues based on familiarity with the ordered major scale. The chromatic illusion replicates the phenomenon over a wider range of time and pitch, and with a chromatic, rather than diatonic, scale.

Figure 1. Stimuli versus percept in the scale illusion (adapted from Deutsch, 1981). Most listeners presented with a stimulus of scales in contrary motion across the same octave, with pairs switching between opposite ears in successive notes, construct a percept that privileges pitch proximity in every aspect of its organization

The glissando illusion consists of highly contrasted sounds: an oboe tone on a single pitch, accompanied by a sinusoidal tone that moves siren-like up and down a gamut of pitches. These two components also trade places rapidly in the stereo mix, but again, our perceptual tendency to connect similar sounds (and segregate dissimilar ones) overwhelms the physical reality of acoustic separation between the ears.

After the tritone paradox, which will be discussed in detail later, a "mysterious melody," though actually quite well known, sounds completely unfamiliar because its tones are presented in a variety of registers and never allowed to flow from one to the other in their usual contexts. (Imagine a similarly disjunct distribution of words through many voice ranges or through another parameter. Whereas it might still produce an intelligible sentence, this disjunction of melodic motion—a principle well known to composers of the twentieth century[9]—renders the tune unrecognizable to most. Once we know what to listen for, the melody is recognizable: Its rhythm, pitch class content, and implied harmony, which are the same in both versions, are now connected to a recently reinforced memory.

Phantom Words and Other Curiosities is the more recent disk, and its aspects are fewer but more varied. Extending the "high–low" illusion mentioned earlier, we explore a number of two-syllable words or word pairs—mostly common names—in the same alternating stereo dichotomies. Deutsch invites us to attend to emergent language sensations that differ fundamentally from the syllables used to construct the stimulus. Because waveforms in contrasting syllables are added to one another, and because of the possible recombination of syllables inherent in slightly overlapping repetitions, we infer some words or phrases seemingly unrelated to the content of the recording. Thus, even listeners born into languages with radically different phoneme sets will imagine words from their native vocabulary in the midst of the complex signal.

This disk also introduces us to Deutsch's wide-ranging research on pitch memory. As with the tritone paradox on the previous disk, we are invited to replicate her experiments on the influence of intervening information in our ability to remember and compare pitches. Deutsch demonstrates here that memory for pitch is both separate and different from our memory for language (Deutsch, 1970). Intervening words—in this case, spoken numbers—do not significantly impede our memory, whereas intervening pitches do. (A small thought experiment should also clarify that no kind of intervening information is likely to impede our short-term memory for a color, a shape, or a word; pitch seems a unique category in this respect.)

Deutsch has studied pitch memory in other ways, determining the very slight influence of binaural separation (Deutsch, 1978) and a surprisingly orderly influence of microtonal pitch differences—differences of less than a semitone (Deutsch, 1972)—on the same memory task. Even though these may have been less entertaining to a general audience, it would have been nice to have a few more examples to indicate those discoveries.

The disk also contains a rendering of a common voice-leading figure (*cambiata,* literally "change") in an illusion very much like the octave illusion, except that some percepts include interesting rhythm and contour effects.

A demonstration of great aesthetic interest finishes *Phantom Words.* "But They Sometimes Behave So Strangely" is a composition of repeated (and otherwise unmanipulated) speech sounds. When a small portion of the recited speech is played a dozen or more times unchanged, the very fact of its possessing a pulse calls to mind the possibility of music. If affected by the illusion, we find we are processing pitch information from speech (normally an indicator of emotion and emphasis) in the more specific manner that we bring to musical experiences; the phrase begins to sound like a melody. It is not clear how likely the resultant phenomenon is; whether any given speech recording could produce it may depend on chance conditions of in-tune pitch intervals between its syllables. The percept is nevertheless extraordinary in this example because it shifts so easily in and out of consciousness, depending on what we listen for. Despite that flexibility, each percept (both normal speech and melodic singing) seems unambiguous.

In her commentary here, Deutsch cites Modest Mussorgsky's insight that everyday speech contains abundant musical implications; he and other composers[10] have often remarked on the importance of speech sounds as guides to the composition of naturalistic melody. Another point of view attributes the hidden musical percept of a nonmusical sound to the more basic principle of sequence. Most of the discipline of music theory is concentrated on constraints of information (dissonance, consonance, rhythm, progression) that separate what is logical or sensible in a musical style from what is not. However, when music turns to sequence—forming obvious and minimally transformed repetitions of a recognizable figure—the rules are substantially loosened. According to legend, Louis Armstrong often said, "A wrong note is only wrong until you play it three times in rhythm"; he might just as easily have been Deutsch's muse in this example. The notes we "sing" in everyday conversation sound arbitrary until repetition shifts our attention to whatever order can be found in them.

Interpreting the mind's role in false percepts

The octave illusion and the tritone paradox, though interesting in their own right as acoustic phenomena, are also the subjects of larger debates, and they are evidence of pervasive, but not necessarily obvious, determinants of auditory information processing. In the octave illusion, Deutsch (1974) explains false percepts in terms of a conflicted mixture of hemispheric dominance–based frequency perception and frequency-based source localization. The differences between perceptions of the tritone paradox have been associated in several experiments (Deutsch, Kuyper, & Fisher, 1987; Deutsch, 1991; Ragozzine & Deutsch, 1994; Deutsch, Henthorn, & Dolson, 2004) with regional distinctions in the octave band of typical speech. Neither of these attributions is uncontroversial, so to provide further insight into Deutsch's work, I will introduce basic arguments about them here.

Grouping mechanisms, handedness correlation, and the octave illusion percepts. The octave illusion, according to Deutsch's early research (Deutsch, 1974, 1975; Deutsch & Roll, 1976), occurs for a slim majority of listeners—mostly right handed—and it sometimes fades with exposure to the stimulus, making the phenomenon difficult for analytic listeners to contemplate. The stimulus consists of "dichotic octaves"—simultaneous notes an octave apart, which are split between headphone channels (Figure 2a) and continually trade places every 250 ms.

Even without the illusions, the stimulus suggests a basic problem in the prediction of how auditory scenes are analyzed by the ears. Schouten (cited in Deutsch, 1999) and others (Tekman, 1995, 1997) view "group identity formation" in music as some function of similarity and difference between a variety of events plotted on two or more dimensions.[11] The following formulation is one way of summarizing common features among a number of musical "group identity" theories, which I have adapted here for use in the discussion of dichotic octaves:

> For any object o, the strength of its association with another object q is a function of two inversely related factors:
>
> Proximity to q in terms of variant dimensions $\{D_1, D_2, \ldots D_n\}$
>
> Distance from *close objects* $\{p_1, p_2, \ldots p_o\}$ terms of the same variant dimensions
>
> In this language, a variant dimension is any for which there are perceivable differences between the examined events.[12]

The two alternating states of the stimulus in the octave illusion consist of four "objects": a high and low pitch originating in each of two locations. The challenge of interpreting the stimulus in terms of interaural separation comes from assigning significance to the proximity "octave" and comparing it to the distance (180°) between left and right on the horizontal plane. When octave proximity prevails in this assignment, the pitch intervals might seem to be separate objects

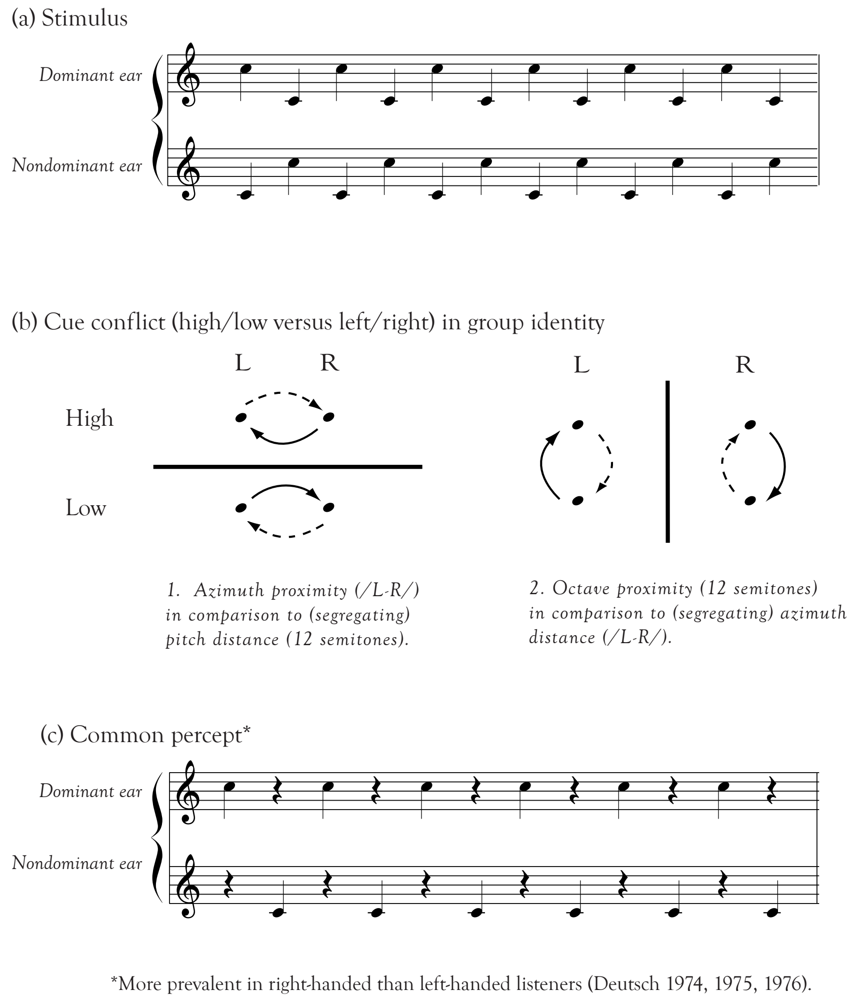

Figure 2. Stimulus and a common percept in the octave illusion (2a and 2c adapted from Deutsch, 1981). We might predict that listeners presented with a dichotic octave sequence (a) would be torn between cues for group segregation (b). A common percept (reported in Deutsch, 1974) cannot be explained in terms of those principles (c).

on the left and right, jumping up and down between high and low pitches (180° out of phase with one another). Conversely, a relative proximity of left and right in comparison to an "octave" distance yields separate objects above and below, each swinging back and forth horizontally (Figure 2b).

Our ability to predict which of these two percepts will result depends on a comparison of values in dimensions of difference that are completely unrelated to one another. If an octave is much less a barrier to "object unity" in this auditory scene than the 180° distance between left and right, then we should hear separate objects jumping up and down. If not, then we might hear separate objects swerving left to right or some shifting fusion of all four object positions.

However, the majority of listeners—those who report the octave illusion—hear only *diagonal motion*: the high tone in one ear alternating with a low tone in the other (Figure 2c). This involves not only the masking or suppression of the other components of the stimulus but also the repeated "false" perception of a low tone in the nondominant ear when that pitch is not physically present.

According to Deutsch and Roll (1976), the illusion stems from the juxtaposition of unrelated tendencies: We privilege high frequencies in the determination of where a complex sound comes from, but we privilege our dominant ear in the determination of pitch when left ear and right ear sensations are in conflict. This is a "double whammy" of percept suppression: First, when the high pitch is in the dominant ear, it takes precedence over the lower pitch in determining source location, and because it enters the dominant ear, it takes precedence in determining the pitch height percept. When the high pitch is in the nondominant ear, 250 ms later, a conflict occurs because while the low tone's presence in the dominant ear gives it priority in determining the pitch percept (low), the high frequency's presence in the left ear triggers localization in that direction. According to Deutsch and Roll, we sometimes resolve this conflict between (unrelated) "what" and "where" cues by recognizing a nonexistent low tone in the nondominant ear, whose pitch is determined by low-pitch sensation in the dominant ear and whose position is determined by high-pitch sensation in the nondominant ear. Not all listeners find the intersection of these conditions, however, and left-handed listeners are less likely to find them than right-handers.[13]

This "suppression model" is a remarkable theory involving factors that are both highly unrelated and subtle, yet well enough balanced with one another that they might conspire to remove two percepts (high note from left, low note from right) and replace them with a ghost (a low note on the left). It should not be surprising that a volley of counterarguments would follow this claim. Chambers, Mattingley, and Moss (2004) offer several objections. They argue first that pitch *fusion,* instead of separation or suppression, is the likely result of binaural pitch cues an octave apart, so that in both of the alternating states, a low fundamental frequency, derived from the waveforms' combined periodicities, should occur. In order to explain nonconforming results collected by Deutsch and Ross, Chambers et al. suggest an alternative solution that combines harmonic fusion with a kind of interaural asymmetry in pitch processing called *binaural diplacusis.* Diplacusis involves minute differences in pitch perception between the ears, leading not to a normal melodic interval sensation but to a sense of flatness or sharpness distinguishing nearly identical notes. In their own replications of the Deutsch experiment, some listeners reported small pitch distinctions, and Chambers et al. argue that these are the real "diagonal" intervals—the ones Deutsch interpreted as octaves.

Deutsch's original reports (1974, 1975) and her reply make clear that slight pitch differences often were reported as additional percepts to the octave phenomenon; she also conducted later tests with skilled musicians who could resolve the interval size controversy with standard pitch notation. Moreover, it cannot be emphasized strongly enough that the microtonal distinctions of diplacusis are a radically different phenomenon from the distinction of an octave, even to musically illiterate or naive listeners. Not only are octaves much larger than the intonation differences of diplacusis, but in the dimension of harmonicity the difference is reversed: Pitches less than a semitone apart are always strongly dissonant, and those an octave apart, being perfect consonances, differ almost not at all. It seems highly unlikely that even unskilled ears would confuse this distinction, and the authors offer no evidence in support of the possibility of that particular confusion.

Chambers et al. make a few more claims based on preliminary experiments; Deutsch asserts that these were not well documented, and some of them were not accompanied by data. Among them are a demonstration that listeners in an experiment using dichotic octaves similar to the Deutsch illusion, but with deviant pitches, had more trouble distinguishing pitch deviance from a low tone than a high tone; they also suggest that low frequencies, rather than high frequencies, are likely to dominate these particular localization processes. In both of these arguments, Chambers et al. hold the notion of high-frequency dominance to an excessively high standard for Deutsch's purposes and succeed only in refuting an idea that is ultimately unnecessary for the suppression model: that frequency would be the *sole* determining factor in sound localization. On the contrary, for the suppression model to work, frequency must play a subordinate, albeit significant, role.

Aside from this technical distinction, however, it often seems that Chambers et al. are arguing not so much against Deutsch's interpretation of the illusion but against the illusion itself. Some of their objections rest on the foundations of what a psychoacoustician should *predict* in Deutsch's stimuli, under the assumption that it will behave as other stimuli do. They explore versions of Deutsch's work at slower tempos and with different pitches, as though any conditional anomaly in sensation—any illusion—would point to some proportionate set of implications in normal sensory processing.

At the core of all illusions, though, is a failure that requires special circumstances, easily overlooked because the conditions of their replication are so precisely constrained. In the case of the octave illusion, the abnormality arises because one of the brain's normal processing habits—to enhance its azimuth localization processes by selective attendance to higher frequencies—betrays its ability to quickly recognize the location of a simultaneous (and ecologically unlikely) lower tone.

Geography, language, and the tritone paradox. Deutsch's tritone paradox involves the unique property of pitch height ambiguity in a complex artificial timbre developed by Roger Shepard. A Shepard tone (ST) is a collection of simple sinusoid tones, all members of the same pitch class and separated by octaves (Shepard, 1964). Their relative intensities are determined by a bell-shaped spectral envelope, so that low and high pitches in the collection resemble "overtones" or component parts of a single complex waveform, and so that the fundamental appears to be somewhere near the peak of the curve (Figure 3).

Jean-Claude Risset and Roger Shepard (cited in Deutsch, 1986) have both demonstrated the paradoxical potential of artificial pitch height ambiguity by repeatedly traversing the circle of pitch classes, steadily adding new octave partials while subtracting them from the other end and leaving the position of the spectral envelope immobile. The result is an impression of infinite ascent or descent (Shepard, 1964; Deutsch, 1986). Because pitch information changes incrementally, and there is little or no change in the total apparent volume of the sound, we do not easily recognize individual pitches appearing from below or disappearing into the inaudible higher frequencies.

An often-cited metaphor for Shepard's illusion is the Penrose staircase mentioned at the beginning of this review. A more apt comparison, if not quite a perfect one, is the revolving "candy cane" barber's pole. Consider each compass point in the rotation of a barber's pole as the equivalent of a specific pitch class and the height of the pole as a range of perceived fundamental (absolute) pitches.[14] Then think of the appearance of any given red stripe in the field of vision as the position of a rising "apparent fundamental." The counterclockwise motion of the diagonal stripes (rightward, from the normal view of the pole) moves each stripe out of view in the same way that an apparent fundamental quiets itself during its ascent, while the emergence of a new stripe resembles the rise of a new fundamental. The cylinder as a whole resembles the amplitude envelope of the ST because it does not change in height. The barber's pole appears to rise infinitely because visible portions of the stripes rise in the visual field, but the stripe at any given height is actually making a 360° rotation. Likewise spectral components rise in an ascending ST, and the sum of them simply repeats a 12-semitone rotation through pitch class space (Figure 4).

In the 1986 experiment mentioned at the beginning of this review (see also Deutsch et al., 1987; Deutsch, 1991), Deutsch played STs in pairs, each separated by a tritone (a melodically uncommon interval that spans exactly half of the octave pitch class circle), and asked participants to judge whether the succession seemed to ascend or descend. This judgment task is the rough equivalent of photographing a barber's pole at 180-degree increments and then asking whether the motion between the photos is clockwise or counterclockwise. Most pitch motions, made of tones with unambiguous fundamental frequencies, are inevitably clear with respect to up or down motion. Wanting to hear these melodic motions as such, participants in Deutsch's experiment are likely to select one strong component in each of the STs (just as you might choose one stripe in each of the photos) and hear the direction of motion accordingly.[15]

Shepard (1964) and Risset (cited in Deutsch, 1999) noted the ambivalence of reports about the half-octave motion with STs, but those investigations focused on preference for proximity in judging a variety of pitch interval directions. By contrast, Deutsch (1986, p. 276) considered the possibility that "the perceptual system will not settle for ambiguity, but will instead invoke some other principle in making judgments of relative height." Despite the near-perfect acoustic ambiguity of the task,[16] judgments of specific tritones remained consistent within the reports

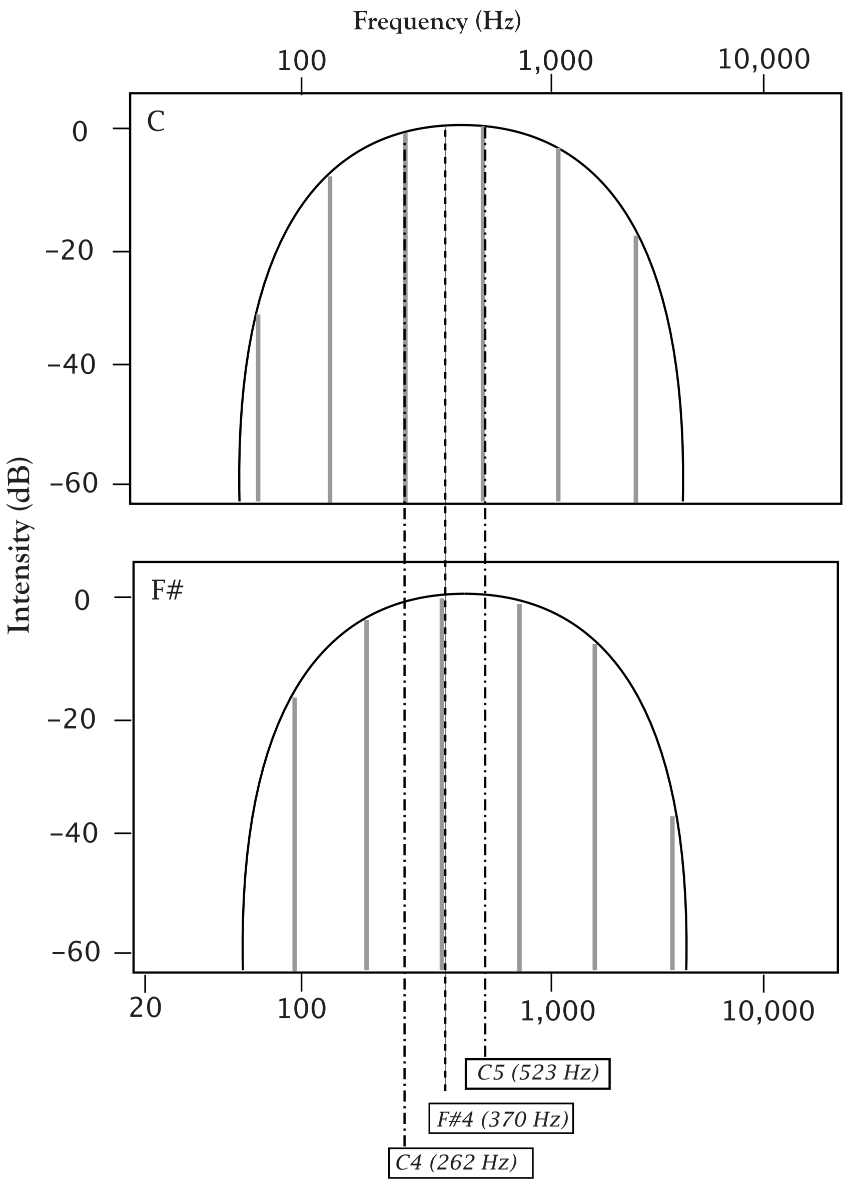

Figure 3. Shepard tone spectral envelopes in the tritone paradox (adapted from Deutsch, 1991). Fixed spectral envelopes determine the energy of partials an octave apart and render pitch height ambiguous. Motion from C (top graph) to F# (bottom graph) is interpreted as ascending by some listeners and descending by others (Deutsch, 1986)

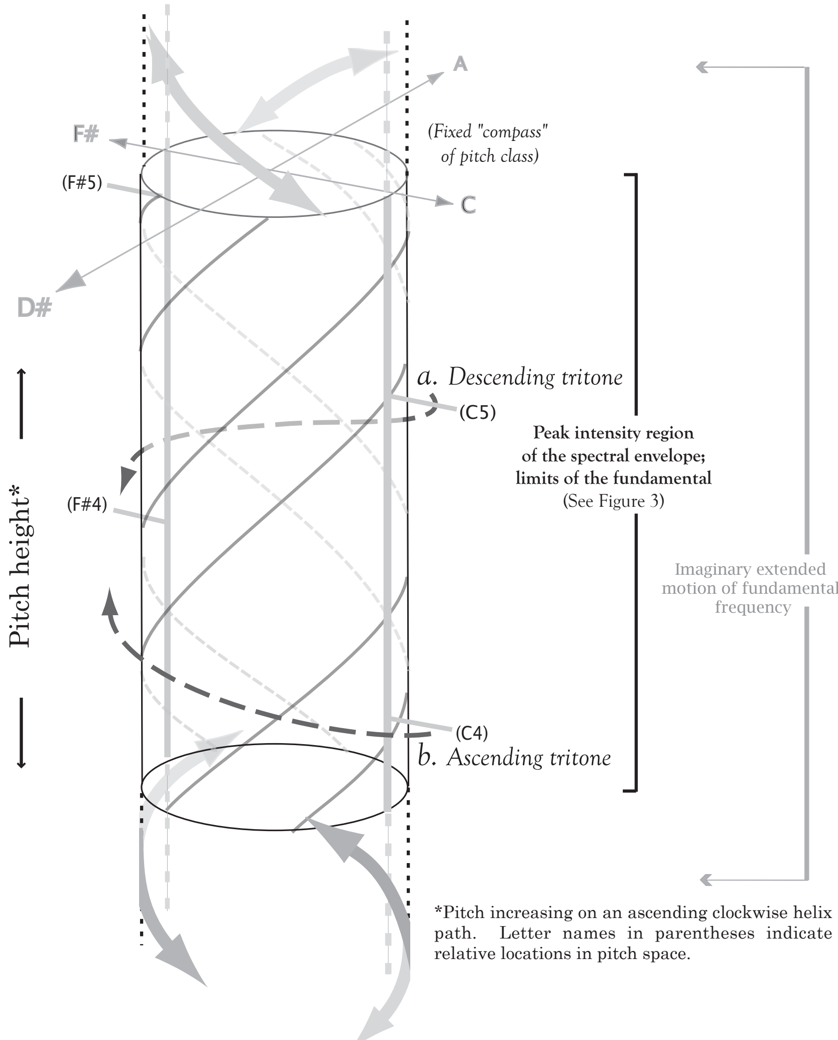

Figure 4. The tritone paradox: a barber's pole metaphor. The percept of the fundamental frequency in Shepard tones a tritone apart can be compared to the stripes on a barber's pole 180° apart. The cylinder resembles Shepard's stationary spectral envelope, and the diagonal direction of the stripes, a half-circle apart, resembles our memory and projections for motion of the individual octave partials. Pitch fundamentals appear to move continuously above or below the limits of the spectral envelope but instead are replaced, unaltered, in the circular motion of pitch

of most participants from trial to trial (Deutsch, 1986; Deutsch et al., 1987; Ragozzine & Deutsch, 1994). Factors related to order of presentation, either for the members of a given pair or for a pair's pitch memory context, had no consistent effect on judgments, and no correlation with musical training was found.

These factors taken together lead to a speculation that people carry with them unique cognitive mappings of pitch class space (Deutsch et al., 1987; Ragozzine & Deutsch, 1994), each bringing to her musical experiences a kind of fixed compass and imagining, unconsciously, one part of the circle of keys always to be "up" and another always "down." As with compass directions, where a resident of the Northern Hemisphere is surprised to learn that someone on the other side of the world will consider the tropics to be in the north, two individuals' "absolute" (if not fully conscious) relationships to D major or A-flat major may be, in some subtle way, orthogonal and incompatible.

In search of a factor to explain consistent variation in tritone paradox judgment, Deutsch hypothesized a correlation with regional variations in the early experience of spoken language (Deutsch, North, & Ray, 1990; Deutsch, 1991). Hypothesizing that a "listener develops a long-term representation of the pitch range of his or her speaking voice, and that included in this representation is a delimitation of the octave band in which the largest proportion of pitch values occurs" (Deutsch, 1991, p. 337), Deutsch et al. (1990) studied listeners' speaking voices. They found some correlation of judgments of pitch height in the tritone paradox, with the specific octave band in listeners' speaking voices. In other words, participants tended to judge as higher the pitch classes near the strained upper limits of their vocal ranges.

In an earlier study (Deutsch et al., 1987), judgments of students at the University of California at San Diego indicated a high concentration of pitch class space representations with C and C# near the top, F# and G near the bottom. Taking a cue from previous studies of regional pitch variation in spoken language and guessing that these results might be related to language acquisition predominantly in California, Deutsch undertook studies of students in southern England (Deutsch, 1991) and in Ohio (Ragozzine & Deutsch, 1994). Deutsch implies, in her subsequent hypotheses, that our linguistic environment determines the octave band of normal speech at an early age. What had seemed initially to be a correlation of individual voice differences was now interpreted as a fixed pitch height compass that applies to larger linguistic communities. (Women's and men's speech ranges are highly concentrated, conveniently for this theory, about exactly an octave apart.)

Marked and statistically significant distinctions were found between Californian and English listeners, whose judgments privileged pitch height roughly in the E–G# range. Interpretation of the results from Ohio is understandably subtler because speech variation under the auspices of U.S. media culture is a messy confound. Nevertheless, by distinguishing between two kinds of rural Ohio natives—those whose parents were raised in Ohio and those whose backgrounds were more complex—Deutsch found that the latter group was more likely to match the "California model" of pitch perception, and results from the former group leaned less distinctively in that direction.

In 1994, Deutsch directly engaged criticism of the study from Bruno Repp (Deutsch, 1994; Repp, 1994). Repp conducted three experiments on mixtures of American, British, and Dutch subjects using a modification of Deutsch's experimental protocols. He confirmed that individuals have consistently different responses to the tritone paradox but was unable to support arguments relating listener reports to their speech patterns.

Repp challenged Deutsch's findings in the domain of linguistic differences by extending her trials to listeners from the Netherlands. However, he did not attempt to distinguish the precise linguistic backgrounds of his subjects, and so his data in this experiment may be unrelated to that thesis as well. (Numerous other studies of the correlation [cited in Deutsch, et al., 2004] have confirmed that correlations can be drawn with areas in Florida, Ontario, Texas, Korea, Sweden, and Greece.)

Repp also argued that we should attempt to correlate tritone judgments with the *lower* end of human vocal ranges because it is a more precipitous limit and because the normal range of pitch in Deutsch's participants had been about an octave (meaning that the pitch class index of both ends of the range should be about the same). This raises important unanswered issues for Repp, however: A map of pitch class "height" obviously could not correlate with both the bottom and the top of an octave range, so his experiments missed any opportunity to address this aspect of Deutsch's hypothesis (Deutsch, 1994). This author finds further trouble with the specific distinctions between the hypotheses. If the upper range of our voices is the determinate, as Deutsch argues, it suggests that we have mapped pitch height to a physical experience of voice tension. Evidence from musical literature of many cultures might provide ample support for this idea. But the possibility that our lowest pitches of speech would be ingrained for any reason as universally low notes is not as easy to fathom.

Finally, Repp wondered how we could hope to correlate mappings of pitch class height with an individual's pitch range and to that of her linguistic community, given the anatomic differences within communities. Deutsch (1994) disagrees with Repp on the significance of this issue, emphasizing that physiological studies showed no reliable anatomic correlation with pitches in speech and that natural speech variation is much smaller than the variation sometimes observed in performance circumstances. It should be added here that most human voices, regardless of gender, break between "chest" and "head" voices at around D#4–E4. Deutsch's hypothesis calls not so much for a correlate of one's potential voice, or voice physique, as for a correlate of speech habits, which might be regularly formed against the grain of biological variety. Nevertheless, the precise relationship between these possibilities may be the next important area of investigation.

The two disks reviewed here—*Phantom Words and Other Curiosities* and *Musical Illusions and Paradoxes*—are on a tangent from these unanswered questions of auditory perception and cognition. But it seems fitting to close by reinforcing the speculation that we connect the sounds of our speech to our ways of organizing the sounds of melody. As I listen back on "But They Sometimes Behave So Strangely," and try to sort through the melodic behaviors of Deutsch's words, I am aware that a particular dialect of speech—outside one's own experience—has always seemed to have its own melody, made more noticeable by its unfamiliarity. Yet Deutsch turned speech into melody and back again, by emphasizing not unfamiliarity but familiarity, by ad infinitum sequential repetition.

Nothing could be more suited to the word *illusion* than a situation like this, in which a stimulus produces such strong ambivalence. Such tentative percepts are, to varying degrees, a feature of all Deutsch's discoveries, and yet the only deception in so many of Deutsch's examples is the unassuming nudge toward an act of listening differently a second time: We turn our headphones around the other way, perhaps, or shift the balance of channels from one speaker to the other. With some change of perspective, either under our control or otherwise, Deutsch persuades us always to reorganize something, and when we do, there is not so much a feeling that the stimulus has led us down the wrong path as one of empowerment over the act of listening, over our relationship to stimuli in general.

One might initially engage the idea of musical illusion and paradox, as I did, with a concern that the differences between music and drawing, or between music and language, are in danger of quiet oversimplification, one forced into the terms of the other. Having started with a doubt as to whether there can be illusion without light, or paradox without doctrine—music truly contains neither—these CDs reminded me instead that the conditions under which music exists in the everyday world are sometimes a willful act of suspension or suppression. Musical experiences require that we juggle the similarities and distances of stimuli, holding some together and keeping others apart, so that something elegant will emerge. With desire itself playing no small role, Deutsch's compositions and research have reminded this author that beautiful music is found not in some orderliness pressed directly upon the auditory organ but in the structure that a listener either will or will not allow.

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Notes

1. Titled with apologies to Gerald Balzano's (1986) "What Are Musical Pitch and Timbre?"

2. Ventriloquism is an anomaly of perception that draws on aspects of normal multisensory speech perception (McGurk & MacDonald, 1976; Massaro & Stork, 1998). But consider that illusions such as these are also dependent on important historical shifts in the meaning and importance of perception. For a quick view of such shifts, refer to Caleb Crane's (1998) discussion of 18th-century writer Charles Brockden Brown. In early gothic novels, the art of throwing one's voice was a common plot element, to be considered not merely a trick but a truly eerie kind of disembodiment. Like other illusions, it enjoyed enough status to form the whole basis of a story's terrifying dramatic crisis.

3. Escher based his drawing on L. S. and Roger Penrose's trick of one-point perspective (cited and featured in Deutsch, 1992) in which a stairway appears to lead infinitely around a closed rectangular path. This illusion depends on us treating a trapezoid (the shape of the illusion on paper) as a parallelogram (the shape of a rectangle viewed obliquely). The percept is corrected with recognition that two of the trapezoid's lines, if interpreted correctly in terms of single-point perspective, would fall short of their corner destinations, leaving the staircase broken in midair.

4. A barber shaves everyone who does not shave himself, and he shaves no one who shaves himself. When faced with the question of whether the barber shaves himself, we cannot answer in the affirmative or the negative without contradicting one of these premises. This paradox is even better in its abstract form, initiated by Bertrand Russell (1903) as the paradox of the set of all non–self-inclusive sets. Most sets containing other sets either contain themselves or exclude themselves, but the set of all non–self-inclusive sets can do neither, and we cannot escape this problem simply by saying that such a set does not exist. It compels us instead to reconsider the very duality of inclusion and exclusion, on which a large portion of human reasoning depends.

5. Of Wagner's intellectually sophisticated harmony, Mark Twain reportedly said, "I am told it is much better than it sounds."

6. "Visual illusion" might be oxymoronic if *il* = "poor or mistaken," *luce/lus* = "sensation of light."

7. More than sounds, images tend to reflect unchanging realities; we can take the time to test them against additional evidence of their referents' existence (Gibson, 1979). Sounds are rarely so stable, and so by the time we confirm (in our other senses) where a sound has come from, the sound is no longer present for the benefit of comparison.

8. James Tenney's (1969) *For Ann (Rising)* makes use of the same acoustic principles that inspired Deutsch's tritone transposition experiments.

9. The dependence of melodic continuity on pitch proximity was used to a productive "negative" effect by composers such as Edgard Varèse, Anton Webern, and their postwar European successors. Their musics undermine the normal conjunction and continuity of pitch information, on which melodic identity partly depends. The resulting sense of departure from tradition may have owed as much to melodic disjunction as to new harmonies or abundant dissonances.

10. Perhaps the first to call for music to lean closer to speech was Jacopo Peri, whose *Dafne* (1596, lost) and *Euridice* (1601) are credited as the first operas and contain examples of *stile recitativo,* a kind of singing that resembles everyday speech communication. Peri wrote extensively on this issue and recognized "that in our speech certain words are intoned in such a way that one can base harmony upon them" (cited in John Walker Hill's 2003 article "Beyond Isomorphism Toward a Better Theory of Recitative," a study that documents numerous early composers' interests in this issue and correlates their accomplishments with modern phonological psychoacoustics).

11. Deutsch discusses temporal coherence, a topic in need of much more exploration. According to Van Noorden (cited in Deutsch, 1999), in order for listeners to hear an alternating pair of tones as a temporally coherent stream rather than a pair of separate streams, a greater distance in pitch between them requires some greater distance in time. Tekman (1995, 1997) develops this principle in relation to horizontal (time-based) grouping processes.

12. For example, in a group of A-naturals, all at 221 Hz, "proximity in terms of pitch" is not a factor affecting the way we parse it into smaller subsets.

13. Most subjects heard only a single sound, moving from right to left in connection with a motion from high to low. Right-handers usually (25/31) heard the higher tone consistently in the right ear, whereas left-handers showed no statistically significant preference.

Right-handers were unlikely to reverse their description when reversing their headphone positions (1/31, as opposed to 4/17 for left-handers) (Deutsch, 1974).

14. This part of the analogy, which distributes pitches along an ascending helix, the circle of which represents motion through any given octave, is a favorite image of Roger Shepard (cited in Deutsch et al., 1987).

15. Others, especially those with experience producing electronic music or organ music, will be likely to recognize that any given pair of STs is a collection of dots that we can connect in a variety of ways. After a few practice runs at the task, this author found himself coming to a decision, always confirmed, after only the first of the tones was played. This may be because an intuitive memory for the distribution of energy across the octave partials led me to a prediction of my own sensitivities to partials in the next note.

16. One possible confound to the "perfection" of the ambiguity is that despite the unchanging sum intensity of all the spectral components, the intensity of components near the peak may differ in sum from pitch to pitch. Deutsch et al. (1987) rule out such pitch-specific effects by distributing specific transpositions evenly in each of a variety of trials containing pitch-specific forms of the envelope. But see later articles by Repp (1994) and Deutsch (1994) for further discussion.

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Aging Artists' Creativity

Aging, Creativity and Art: A Positive Perspective on Late-Life Development

By Martin S. Lindauer. The Springer Series in Adult Development and Aging. New York: Springer, 2003. 336 pp. Cloth, $79.95.

In a brave attempt, Martin Lindauer explores the relationship between aging and creativity among artists in *Aging, Creativity and Art.* From the *Preface* we know that Lindauer was approaching 70 as he completed the book. However, we do not know when he started and how long it took him to complete the exploration.

Readers often skip prefaces of books because they are written in the same formal and mundane style. I suggest that readers not skip the preface this time because it is a rich source of interesting and touching information and questions. The cover of the book is a self-portrait of Rembrandt. In the first paragraph of the *Preface,* Lindauer uses Rembrandt's self-portrait to posit a series of questions central to the phenomenon of aging. We may ask, Why did old Rembrandt spend time and energy on a self-portrait? Apart from artistic reasons, is it related to the artist's self-fulfillment, self-exploration, or some other life goals? Similarly, we may ask, Why did Lindauer choose to spend time and energy on finishing his book? Apart from scientific reasons, is it related to the author's self-fulfillment, self-exploration, or some other life goals? The *Preface* may provide some clues as to the statements artists and scholars intend to make. Indeed, this book may provide a rich source of information and insights about creativity in the exploration of human development in general.

The book starts with two chapters that provide an overview of the relationship