Auditory Illusions

ELA2020 - Acoustics and Psychoacoustics 1

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Abstract

Illusions are sources of delight and wonder. Illusions are tools for discovering mechanism of perception. Illusions function as weapons and protection through the evolution of all species with senses. Illusions are of similar interest for scientists - trying to decode them – and artists – employing them for their “magic”. They are a good way to illustrate how science and art blend into each other and even *depend* on each other.

Looking through publications on the issue I have found numerous different approaches from various directions and fields of research: Biology, Psychology, Physiology, Psychoacoustics, Fine-Art, Composition etc.

This essay will introduce some basic concepts and ideas about illusions which I found particularly interesting. It will mainly focus on the auditory domain utilising some examples. However, much more is left out than is included but still I hope to give an interesting overview of a fascinating subject. Finally I will draw some conclusions concerning my own practical usage.

1. All senses

"Illusions are essentially phenomena of perception. They cannot be phenomena of the physical object world for they are systematic deviations from physical fact." (Gregory, 1979, p.49) It is important to stress that they appear for *all* different senses and are not exclusively phenomena of visual perception. Going through publications on illusions it cannot be overlooked that research has been mainly devoted to visual illusions in a modern tendency to separate the various senses and to overvalue the visual domain. However there is enough proof to stress the holistic character of human perception, a notion of *synaesthesia,* as for example the different senses check each other for calibration. Moreover there are numerous interesting analogies in visual and auditory illusions that suggests both senses utilize quite similar underlying mechanism and processes. In a similar notion Roger Shepard (1999b) concludes his essay "Stream Segregation and Ambiguity in Audition" with the following words:

> "It should not be surprising that some of the same underlying perceptual principles apply to more than one sensory domain. After all, our sensory systems evolved to respond to stimuli that exist in the same physical environment, regardless of the sensory modality employed. The smell, touch and sight of a flower work in complementary ways to create a mental representation of the object in the world. And many of us are familiar with the interaction of the senses. Without smelling it first, an apple is often indistinguishable in taste from an onion.
>
> Some differences between the senses are to be expected because of the different ways our sensory transducers pick up the information. The important thing to remember is that our senses of hearing and vision, as well as of taste, smell, and touch, are designed to give us information about the same objects in the physical world."

2. The real thing

Recording Technology has introduced the greatest illusion: listening to a concert while being at home.

In the beginning of the 20th century people entering a store were asked to try the *Edison Realism Test*, which was introduced to demonstrate the similarity between concert and record experience: People were asked to take a seat in a quiet space near a phonograph, surrounded by photographs of musicians and concerts. Then they had to choose a record, close their eyes and try to remember the last time they listened to that kind of music in a live situation. When the pictured scene was clearly in mind the record started.

"If you follow those directions exactly, you will supposedly get the same emotional re-action experienced when you last heard the same kind of voice or instrument." (After Katz, 2004) This test was obviously designed in praise of the illusion: back then listening to music all alone was a particularly odd experience and a remarkable event. Mark Katz (2004) cites some turn-of-the century advertisements describing recordings as "lifelike," "a true mirror of sound," "natural," and "the real thing."

The campaign "Is it live, or is it Memorex?", was launched just 20 years ago and has become an icon for *the real thing.* It demonstrates that the notion of a *live experience at home* is not yet completely obsolete.

Today we are pretty much familiar with this so called *acousmatic listening situation* (Chion, 2002), where no musician or obvious sound source is present. Still, to some extent we are able to follow the illusion and actually believe to be in a concert hall while listening to music, or to imagine ourselves to be in another place while listening to soundscape recordings. In order to enhance the illusion, we often *deliberately* shut our eyes to repress all visual clues that prove the opposite. We force ourselves to disable critical reasoning in a notion of “willing suspension of disbelief” – as the poet Coleridge put it.

Gombrich (1979, p. 196f.) points out that the most famous trademark of any gramophone firm is the picture of the dog listening to “His Master’s Voice.”

“The picture makes the same claim for illusion by appealing to the reaction of an animal that the ancients made for masterpieces of painting.” He stresses that the capacity of a painting to deceive animals has always and foremost in ancient times, been proof of its excellence.

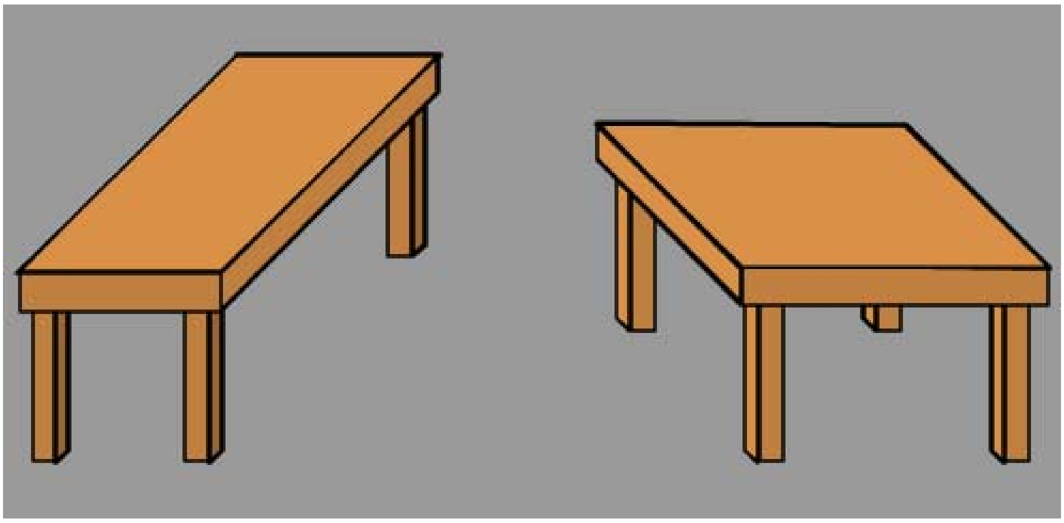
3. Cognitive Psychology

To understand the nature of illusion it is important to acknowledge the difference between physical signal and internal representation. Perception is not a mere copying of signals derived from an objective physical world. A traditional and still not abandoned theory of perception states that “perception is an immediate (and God-like) knowledge of external reality" (Gregory, 1979, p.50) - an act of passive assimilation. A lot of people still tend to back up this theory: We see, hear, smell, taste or feel stimuli that impinge upon our senses.

When Pierre Schaeffer wrote his programmatic "Traité des objects musicaux" in the 1960s it was even more common to favour this theory of *passive perception*; so he wrote several pages as a formal critique of this theory. Michel Chion (2002) sums this critique up:

> "It is true that CORRELATIONS between the variations of a physical signal and those of the perceived sound object which corresponds to it are narrow, but they cannot be reduced to a linear copy. It is the job of psychoacoustics to study these connections, from simple physical examples (pure frequencies for example), particularly all phenomena of deformation (anamorphoses) which occur when moving from one position to another, as a result of the PHYSIOLOGICAL properties of the ear and the PSYCHOLOGICAL elements which intervene in the act of audition. By showing that in certain cases the ear perceives fundamental notes which do not physically exist, but which it reconstitutes in accordance with the spectrum of their harmonics, the active role of the ear in constructing and defining the characteristics of perceived sound is brought to our attention."
>
> "The study of these correlations therefore consists of examining a certain number of these examples where perception apparently contradicts or problematizes the measurements indicated by the physical signal: not because it is blurred or deceptive, but because it possesses its own level of inherent objectivity which cannot be reduced to the worlds of physical phenomena."

Obviously the study of illusions is a powerful method to decipher those *correlations* as it is their nature to *contradict or problematize the measurements indicated by the physical signal.*



The above illustration is one of the most famous optical illusions. It illustrates the basic notion that we have *learned* to see 2-dimensional objects as 3-dimensional, adding depth to a surface. The physical stimulus on the retina is indeed quite different to our internal representation of the objects, as we perceive tables of different sizes. However, the two parallelograms are exactly same in size (use a ruler to prove it). The process controlling this works unconsciously; we are unable to control it, to simply switch it on or off.

One of the greatest proponents of cognitive psychology was Hermann von Helmholtz (born 1821) who introduced the term “unconscious inference” and interpreted perceptions as *conclusions*. He was the first to point out that:

- The perceiver plays an interpretative role in what is perceived.
- Previous experience influences perceptual and cognitive processes.
- These processes mostly occur without conscious awareness.

All these modes and mechanisms play together to create complex *conclusions* that build in the end to a more or less accurate representation of a *reality* surrounding us. The use of the word inference doesn’t mean that all perceptions are just “probalistic guesses,” (Shepard, 1999a, p.24) although situations can occur when cues available are insufficient, and conscious inference becomes a “random guess-like process.”

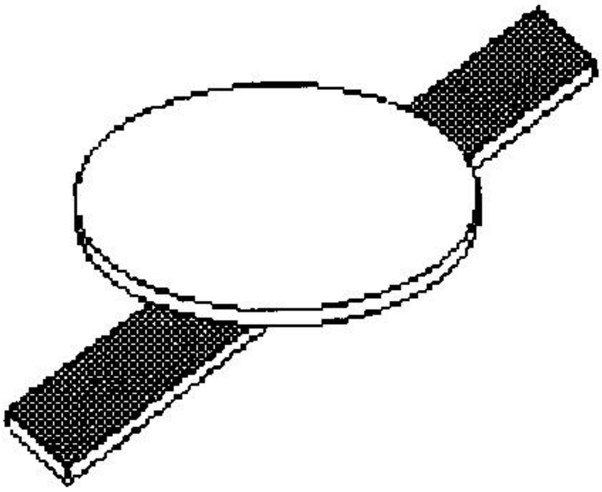
3.1. Perceptual Hypotheses

Perceptions are not certain in so far as our senses might work incorrect, we might be drugged, etc. Everyone is familiar with a feeling of uncanniness when it is dark and certain shapes in the background are unidentifiable and distorted. If incoming information is insufficient we have to do some top-down processing, starting from what we already know (memory) to infer what is going on. Actually “there seems to be no sudden break between perceiving an object and guessing an object” (Gregory, 1973, p.61).

R. Gregory makes the point that sensory simulation is like providing data to set up *hypotheses* that represent the state of the external world. He calls these hypotheses “perceptual hypotheses.” This process is analogue to hypothesis-building in science and consequently he concludes that perception is similar to science itself.

3.2. Perceptual Completion

One principle we employ to complete insufficient sensory data to build coherent hypothesis is called *perceptual completion*.



The above illustration is likely to be perceived as being one object covering the other. Although we cannot be completely sure (the presented information is insufficient), we perceive the bar as continuous. The perceptual hypothesis we build is the most probable interpretation - most likely to be expected in the outside world.

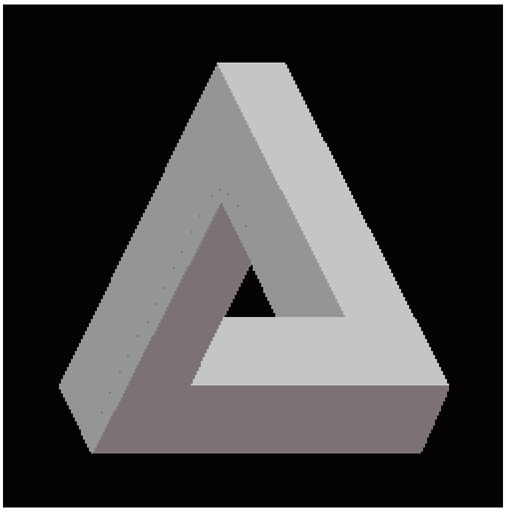
Al Bregman and Valter Ciocca demonstrated an interesting analogy in the auditory domain. They showed that a (gliding) tone that is interrupted by a noise burst is perceived as continuous, although in fact it is not. Therefore perceptional completion for the auditory domain means that a sound may be masked by another sound, yet we may hear the sound as continuous through the mask.

The example on the CD [track 2] presents a steady state tone with a 150ms gap in the middle. After a few seconds the same tone is played again and a 150ms noise burst is inserted to fill the gap. The tone is now likely to be perceived as continuous. On a webpage [1] advised by Albert S. Bregman there are some more well documented hearing-examples of such illusory continuations.

3.3. Paradoxes

As already mentioned, perceptions of objects are mere *conclusions* given by *inference* from data from the senses and stored by memory. Consequently, perceptions can possibly be *false* - the perceived objects themselves can not be *false* as they exist as real objects in a real world. From this viewpoint, illusions can be regarded as “symptoms of fallacies and unwarranted assumptions about the world of objects” (Gregory, 1973, p. 51). This means that they are of similar importance as *paradoxes* for philosophers concerned with arguments.

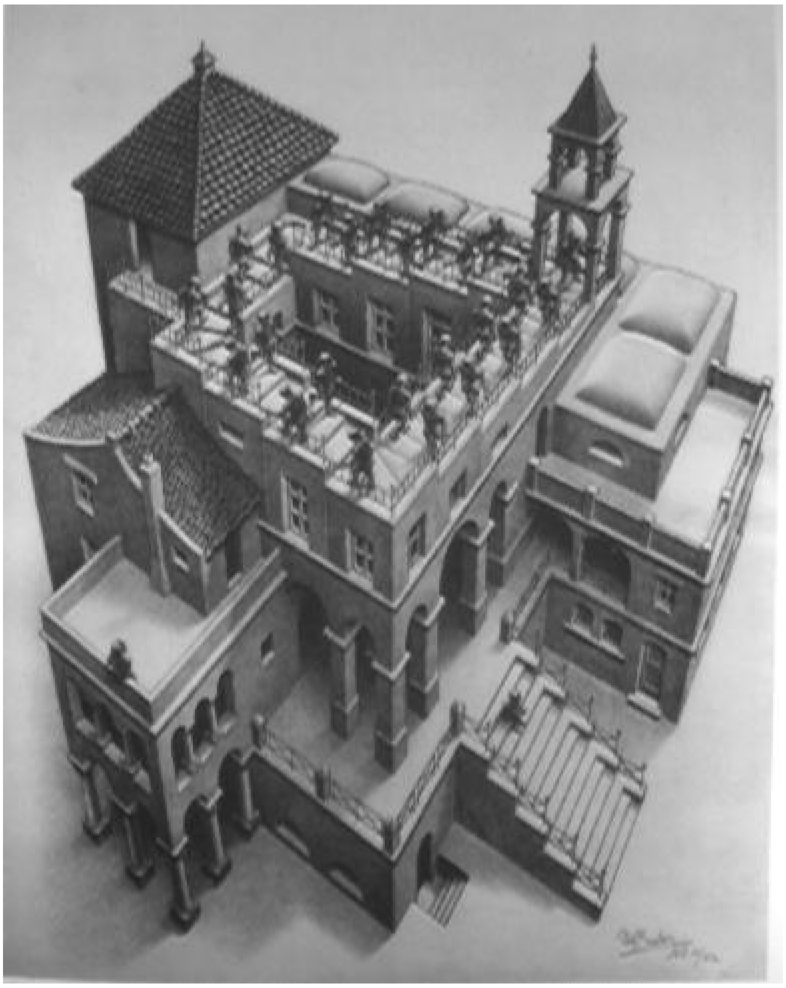
Illusions generated by paradox occur when incompatible data is presented; when incompatible features are combined in a way that contradicts real world experience. The most popular example is the “impossible” triangle by Roger Penrose.



The real world object itself *cannot* be paradoxical or false; consequently only our internal representation is paradoxical. In the case of the impossible triangle this is because we cannot stop to see a three-dimensional object, which in fact is not there. We are unconsciously forced to make a paradoxical interpretation of a non-paradoxical object. Considering this, it becomes evident why the study of illusions is so important and informative for cognitive psychology –

because what constitutes an illusion is only determined by our internal processing, which determines how we perceive.

A lot of artists use juxtaposing data in odd ways to generate complex paradoxes, as the effect is extraordinary and sometimes even irritating. Among most notably, M. C. Escher, whose work is based on the amusement that carefully calculated visual absurdities can produce. Here is one of his most famous illustrations, the endless staircase, a visual paradox in the most classic form:

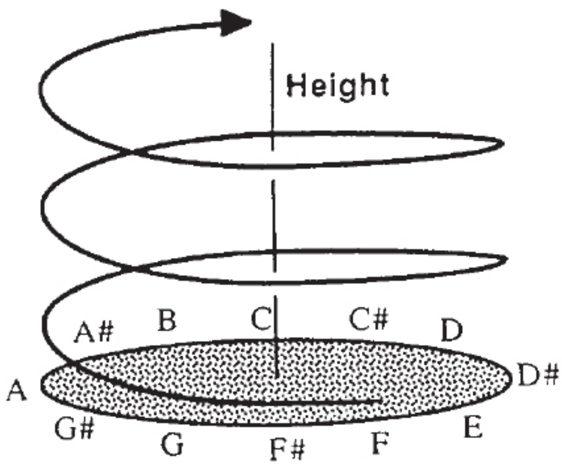


The endless staircase, continuously tricks the eye into a never ending journey. Interestingly, this paradox has a rich set of acoustic counterparts introduced by Roger N. Shepard in the early 1960s.

Shepard Scale

Back then he synthesized a sequence of tones moving up an octave. When this pattern is repeated one doesn’t recognise a starting and ending, but perceives an endlessly ascending sequence of tones. Listen to this paradox on the CD [track 3].

To understand this paradox some basic information on pitch perception is necessary. The pitch of a tone can be described by using two variables: Firstly the dimension *height*, which defines the position on a continuum from low to high. Secondly the *pitch class*, which defines the position within an octave. These relations can be visually summed up in the form of a regular helix:



This model leads to an immediate assumption: it is nonsensical to ask whether one tone, say, *C*, is higher than another, such as *E*. To clarify the question, one would need to give the octaves in which the two tones occur.

Roger Shepard was the first person to experiment on the basis of the helix model. He discovered that when the dimension *height* is suppressed, all tones related by an octave could be mapped to single tones. Visually spoken, the helix becomes a circle and consequently judgements of height becomes *circular*.

Shepard generated a series of tones that were clearly defined in terms of pitch, but poorly defined in terms of height. Each tone consisted of a set of octave-related sinusoids, the amplitude of which is scaled by a fixed bell-shaped spectral envelope. Tones of this kind are today known as “Shepard Tones”.

Shepard found that when two such tones were played one after the other, subjects heard either an ascending pattern or a descending one. The perceived direction depended on the distance separating the two tones along the pitch class circle because listeners always followed the shorter distance between two tones. For example, subjects heard the pair *C#-D* as ascending, because the shorter distance here is clockwise. Analogously, the pair *A-G#* was always heard as descending. Judgements were determined almost entirely by *proximity* along the pitch class circle.

This finding enabled Shepard to produce the striking *Shepard Scale* described before. A series of tones repeatedly traversing the pitch class circle in single steps appears to ascend (or descend) endlessly in pitch.

Jean-Claude Risset produced an intriguing variant. He created a single tone that glided around the pitch class circle in a clockwise (or counter-clockwise) direction. The tone appeared to ascend (or descend) endlessly. He used this principle with great effect in his composition for the play, *Little Boy*, by Pierre Halet. In this piece, a tone gliding down is used as a metaphor for the bomb falling down on Hiroshima – it falls endlessly. Listen to such an effect on the CD [track 04]. Moreover Jean-Claude Risset transferred this illusion from pitch to rhythm and produced an illusion called:

The Increasing Beat

The mind grasps any pattern of sound that is repeated and considers this pattern a rhythm. An inherent property of any rhythm is tempo, or the speed of the rhythm. The illusion is then to let a beat seem as though it is getting faster, when in fact it is not. Similar to superimposing octave related components for Shepard Tones, this illusion is created by superimposing drum beats that have geometric relationships (whole note to a half note, half note to quarter note, etc.). The illusion is created by slowly fading out the slower beat while fading in the successive faster beat. By superimposing these drum patterns, the mind latches onto self-similar patterns of drum beats, as they become dominant in amplitude without necessarily realizing that it does so. Although the effect is not as impressive as the Shepard-Scale, it is quite inspiring to listen to it: CD [track 5].

3.4. Ambiguity:

What happens if the sensory input is ambiguous so that no single hypothesis is more likely than other possible interpretations?

In the visual domain, the famous reversible illusions are examples of ambiguous sense input:

Do you perceive a saxophone player or a woman’s face, an Indians face or an Eskimo? Data of this kind offers two consistent hypothesis of equal probability. It is not possible to perceive both interpretations at the same time but rather to *spontaneously switch* between perceptions.

> “It is perhaps logically confusing to say that data are ambiguous. It is hypotheses which may be ambiguous, when data are insufficient to decide between alternative hypotheses. Whether available data will suffice will depend upon the prior probabilities of alternative hypothesis in the running for selection. There are many interesting and important effects related to rivalry and spontaneous switching between alternative hypotheses.” (Gregory, 1973, p.85)

An analogy in the auditory domain is when subjects are presented with two Shepard Tones that are separated by exactly half an octave (tritone). In this odd case, proximity can’t help to judge relative pitch as the two tones are in opposite positions along the pitch class circle. Experiments prove that ascending and descending judgements occur equally often, as both hypotheses are in fact equally valid. Going one step further from these findings, Diana Deutsch introduced the:

Tritone Paradox

Deutsch (1986) had subjects listen to ordered pairs of Shepard Tones that were separated by a tritone. They reported in each case whether they heard an ascending or a descending pattern. Again, the judgements differed from one subject to another. Consequently melodies can be invented that are perceived completely variably by different listeners. This follows the concept of perceptual ambiguity saying that the same physical stimulation can give rise to different perceptual interpretations.

Listen to the Tritone Paradox on the CD [track 6]. The presented patterns are: c-f#; a#-e; d-g#; f-a. Compare your judgements with those of other listeners.

Deutsch also showed that patterns that are perceived as ascending suddenly become descending (and vice-versa) when transposed into another scale. This finding completely bowls down the principle of *perceptual equivalence under transposition*, which was thought to be universal.

She points out that these effects also occur using more complex sounds, resembling natural instruments. Consequently, these effects might well be found in natural music, “when the composer has introduced ambiguities of height, such as in orchestral pieces by Debussy and Ravel.” (Deutsch, 1999b, p. 390)

3.5. Hybrids:

As already mentioned there is no sudden break between *perceiving an object and guessing an object*. Everyone knows of "(…) feeling satisfied that a stick lying in our path is insignificant, only to be suddenly disturbed when it moves and found in reality to be a snake" (Gregory, 1973). This moment of shock and surprise has often been used by artists that have based their work on this uncertainty we have to deal with when we identify objects.

In the 1970s, the game with such *changes of identity* became very common in the arts. The likes of Alberto Giacometti, Salvador Dalí, Joan Miró, André Breton, Oscar Dominguez, and Man Ray invented new kinds of objects by freeing trivial objects from their utilitarian context, and combining them with others that have also departed from the principles of real world. *Hybrids* or *Dreamed Objects* like "Emak Bakia" by Man Ray – the neck of a violin and a tress of blond hair instead of strings. The theorist behind the Surrealist movement, Andre Breton, spoke of the "crisis of the object."

Now, decades later, with modern studio technology available it is possible to transform and manipulate sound-material in any thinkable way. Consequently, we can create sounds that resemble two or more traditional instruments - generate *hybrids*. The "crisis of the object" has finally reached the *sound-object* too.

As we are used to perceiving traditional instruments with their typical harmonic spectrum and timbre, the perception of such hybrids is very peculiar. One sound synthesis technique that allows various un-natural combinations of known instrumentarium is physical modelling.

"Starting from existing identities, they are the result of Frankenstein-luthiers working to inflate size, distort shape, hybridize identity, and amplify particular timbral qualities. Such instruments designs could be said to result from *splicing genes*. But within a physically plausible space, leaving perceptual schema intact." (Chafe)

To name just one example, in his project “S-Morphe.S,” the sound artist Matthew Burtner [2] melded the acoustics of a soprano saxophone and a singing bowl into one instrument. The perceived sound is in fact quite odd; musical hybrids can be generated in a dream or a hallucination of new creation. Listen to a short extract of the piece on the CD [track 7].

3.6. Stream Segregation/ Separation Phenomena:

One of the main tasks for our auditory system is to analyze and re-organise the acoustic spectrum we are confronted with. We always try to separate superimposed sounds and link them back to different sound-sources. This is called *stream segregation*.

Moreover, elements are grouped together according to some rules along the *dimensions:* amplitude, frequency, temporal position, spatial location, or some multi-dimensional attribute such as timbre. Along those dimensions, several principles for grouping are utilised. The grouping principle *proximity* (which we got already to know in connection with judging relative pitch) is one of those *Gestalt Grouping Principles*. “It seems reasonable to assume that grouping in conformity with such principles enables us to interpret our environment most effectively.” (Deutsch, 1999a, p. 300) For more detailed information refer to the downloadable .PDF [3] “Grouping Mechanisms in Music,” by Diana Deutsch.

An analogy invented by Alan Bregman (1990) cleverly describes these great abilities of our auditory system:

> “Imagine you are on the edges of a lake and a friend challenges you to play a game. The game is this: Your friend digs two narrow channels up from the side of a lake. Each is a few feet long and few inches wide and they are spaced a few feet apart. Halfway up each one, your friend stretches a handkerchief and fastens it to the sides of the channel. As waves reach the sides of the lake they travel up the channels and cause the two handkerchiefs to go into motion. You are

> allowed only to look at the handkerchiefs and from their motions answer a series of questions: How many boats are there on the lake and where are they? Which is the most powerful one? Which one is closer? Is the wind blowing? Has any large object been dropped suddenly into the lake?
> Solving this problem seems impossible, but it is a strict analogy to the problem faced by our auditory system. The lake represents the lake of air that surrounds us. The two channels are our ear canals, and the handkerchiefs are our ear drums. The only information that the auditory system has available to it, or ever will have, is the vibration of those two ear drums. Yet it seems to be able to answer questions like the ones we were asked by the side of the lake: How many people are talking? Which one is louder, or closer? Is there a machine humming in the background? We are not surprised when our sense of hearing succeeds in answering these questions any more than we are when our eye, looking at the handkerchiefs, fails."

There are several illusions that are based on these mechanisms of separation and grouping:

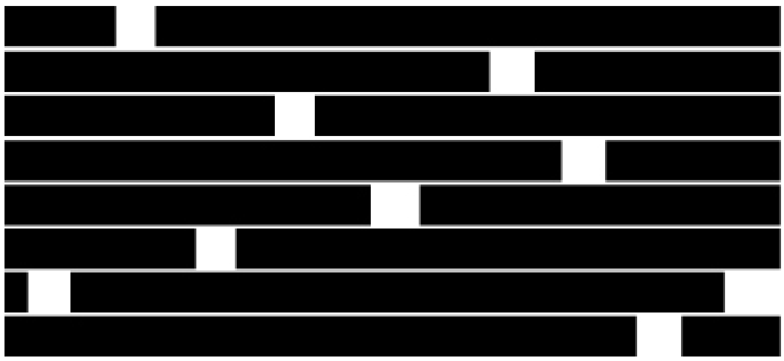
If two sounds are highly correlated (along several dimensions), they will likely be perceived as coming from the same sound source. On the other hand, if they are asynchronous they are likely to be perceived as originating from two different objects.

Melodies for example tend to move in small steps, as large and rapid jumps would segregate a melody into separate streams. The same applies to large differences along all other *dimensions*. If for example two known melodies are played simultaneously, in the same pitch range, with the same loudness on the same instrument, it would be almost impossible to recognise them as separate entities. Strangely, by making one melody quieter, it would become recognisable – what seems to be a paradox.

[track 8] of the CD is a mixture of two Bach Fugues (Fugue No. 2 from Book 1 of the 48; Fugue No. 2 from Book 2 of the 48). After 30 seconds one is lowered in amplitude (5db) which makes it easier to separate the two streams.

Warren and Warren and David L. Wessel described similar findings for the dimension of timbre in great detail.

Kubovy demonstrated that it is possible to generate something like a *melody of silence* by turning on and off components off an eight-tone chord abruptly at different times. Therefore, melodies can be created only by turning on and off components of complex sounds.

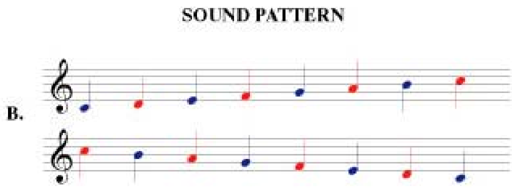


The black bars represent the continuous sounding components of an eight-tone chord. The short temporal gaps make a melody. This seems a reversal of figure (sounds) and ground (silences). The listener will hear a clear melody, picking up not the onsets of the silences but the terminations of the silences (the onsets of the tones).

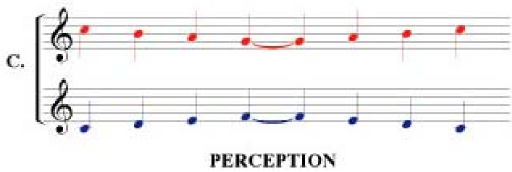
[track 9] on the CD is a pattern produced by superimposing six e-piano tones that are alternately turned on and off.

Scale Illusion

Another interesting finding by Diana Deutsch is that grouping of pitch is in preference to grouping by incoming ear. The illusion that illustrates this fact is known as *scale illusion*. The pattern used consists of a major scale with successive tones alternating from ear to ear. The scale is played simultaneously in both ascending and descending form; when a tone from the ascending scale is in the right ear, a tone from the descending sale is in the left ear, and vice versa. The figure below illustrates these relationships; blue colour means left ear; red colour means right ear:



When heard stereophonically through earphones, listeners often perceive one melody corresponding to the higher tones to be coming from the right earphone, and a melody corresponding to the lower tones to be coming from the left earphone. This perception is again illustrated in the below figure (Interestingly most lefthanders perceive the illusion differently):



Listen to this illusion on the CD [track 10]. To get the optimal result, it is necessary to use stereo-headphones. After listening to it, twist your headphones, listen again, and compare your perceptions. [track 11] is an interesting variation produced by Diana Deutsch.

Note that some of the high tones, although heard on the right, are actually presented to the left ear. Consequently, the scale illusion provides a useful way of differentiating between "ear of entry" and perceived location in auditory perception.

4. Conclusion

As we have seen through various examples auditory illusions offer fascinating possibilities to play tricks on our perception. Human perception is still a relatively unknown terrain and it became obvious that illusions are excellent devices to explore it. With enough imagination almost everyone is able to invent new illusions as the technology is at our hands.

With modern equipment we are now in the unique position to be able to synthesise sounds in whatever shape we want them to be - a universe of exploration opens up. The traditional set of sound effect processors (reverb, delay, etc.) has threfore been enriched with a set of effects that are based on perception-mechanisms, much to our delight and fascination.

The contemporary artist that has a profound knowledge of technology is therefore in the perfect position to create unique pieces that are based on the illusions our perception creates. The illusion itself has not necessarily to be the topic of the musical work but it can be employed to push the music to another, a more *magical* level.

Diana Deutsch has just recently released a new CD called “Phantom Words and Other Curiosities” on which she presents various illusions in a musical context. In this work she mainly focused on the paradoxical relationship between speech and music - to come across just one topic that has been overlooked in this essay completely:

> “The CD is named after the first few tracks, which contain sequences of repeating words and phrases that arise simultaneously from different regions of space. These illusions should be heard through stereo

> loudspeakers that are placed in front of you, with one to your left and the other to your right. The words coming from the different spatial locations are offset from each other in time. As a result, listeners are given a palette of sounds from which to choose, and so can create in their minds many different combinations of sounds. After continuous exposure to these repeating words, listeners begin to 'hear' words and phrases that are not really there. These 'phantom words' are generated by the brain in an attempt to extract meaning from the chaos of sound that is presented." (Deutsch, 2003)

Considering what I have dealt with in this research there are two directions I definitely want to follow in realising my own future projects:

The first concerns the notion of *infinity*. I am really fascinated by the possibility to create seemingly endless evolving patterns. My plan is to program an algorithmic patch that employs Risset's increasing beat as rhythmic basis and Shepard's scale illusion as pitch basis. Alternations and variations in tempo, timbre and pitch (harmony) shall be governed by some chance operations, in order to keep the output interesting and varied. The patch should produce sound without the need of a user or performer and play all by itself. In the end the system should act and sound like a naïve attempt to reach the sky or heaven, never falling back, never looking back.

Secondly, utilising some knowledge on auditory illusions, it is possible to deliberately construct music that is perceived differently by every listener; differently not because of different likings, background or knowledge; differently because of something more basic, the perception process itself. This is a fact I was not aware of before exploring this subject. I definitely want to explore this feature and incorporate it in my music production especially in connection with Deutch's findings concerning tritones and panorama perception.

I feel that dealing with these techniques can introduce a new kind of sensibility to the production of music and even to the perception of music – that's what we can praise illusion for!

Content of the CD

[audio tracks]

[02] *Illusory continuity of a steady-state tone*

[03] *Shepard Scale*

[04] *Gliding Tone*

[05] *Risset Beat* (example from: http://www.noah.org/science/audio_paradox/) (2005-05-12)

[06] *Tritone Paradox* (example from: http://psy.ucsd.edu/~ddeutsch/psychology/deutsch_research6.html) (2005-05-12)

[07] *"S-Morphe-S"* by Matthew Burtner (courtesy of the composer, from: http://ccrma.stanford.edu/~mburtner/) (2005-05-12)

[08] *Amplitude Segregation* (Bach Fugues)

[09] *Melody of Silence*

[10] *Scale Illusion*

[11] *Scale Illusion* (Deutsch variation) (example from: http://www.philomel.com/musical_illusions/description.html#scale) (2005-05-12)

[data track]

These Max/MSP Patches can be considered as additional "gimmicks," but are not the main concern of this research.

Shepard Scale Midi

A tiny patch that allows any Synthesizer (that can be addressed from Max via Midi) to play a Shepard Scale.

Melody of Silence

Seven sinusoids in harmonic relation make up a complex tone. As described components can independently turned on and off to generate a *melody of silence*.

Increasing Beat

A very simple illustration of the increasing beat illusion.

Increasing Beat Complex

A complex variant of the increasing beat illusion described by Risset (1989) in his article "Paradoxical sounds". The user has to load an appropriate sample as sound source.

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