Music 175: Cognitive Psychology and Music

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Information, Perception, and Cognition

- There is a chain of processes between **physical events** and **their perception** by humans:
  1. generation of energy
  2. transmission of energy from event to observer
  3. reception and processing by ear/eye
  4. transmission of signals to the brain
  5. more processing: interpretation, formation of a representation
- **Cognition:** set of *mental abilities and processes* related to knowledge: attention, memory, judgment, evaluation, learning, understanding, remembering;

Information to Representation

- **Information**: what is happening on the surface of the retina or the basilar membrane provides *information* of the external world.
- **Representation**: In the final processing, the brain uses information to construct a *representation* of what is going on.
- Cognitive psychologists are principally interested in the final representation.

Two Tables

- Consider two tables as if in different orientations in space.

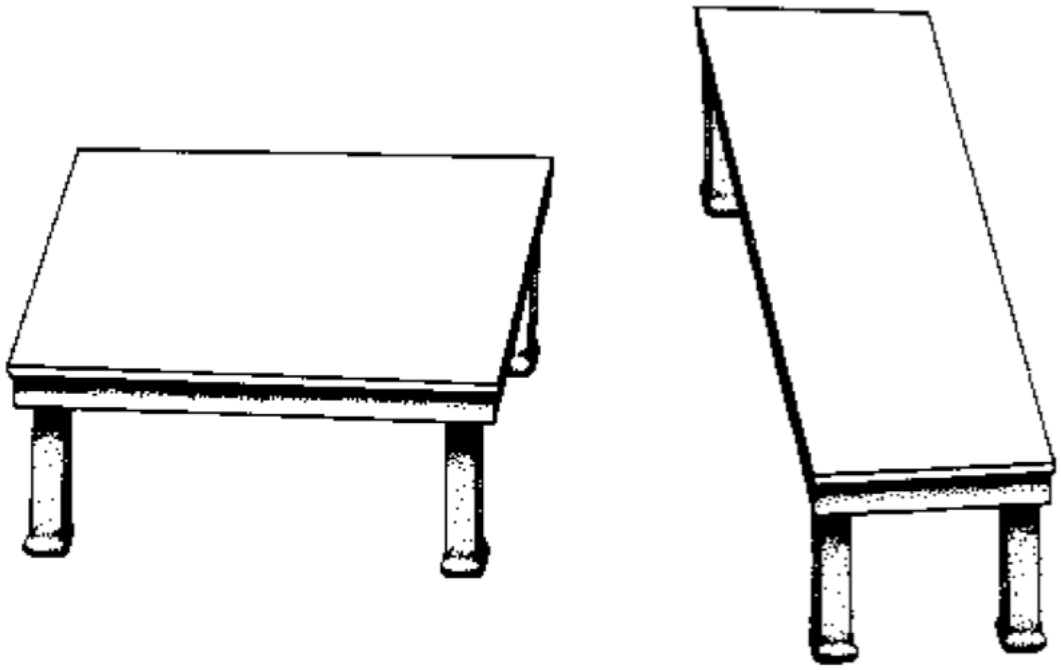
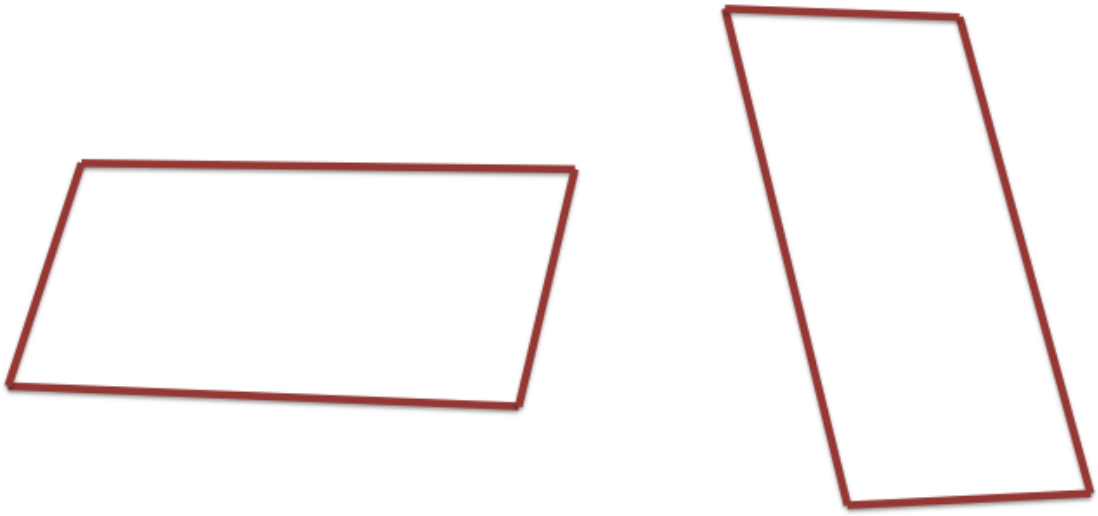


Figure 1: Two tables vs. two parallelograms that are the same size (Cook, Chapt. 3).

- Stating they are tables is a *cognitive interpretation*.
- Patterns of lines are being interpreted as 3-D objects.

Removing Cognitive Interpretation

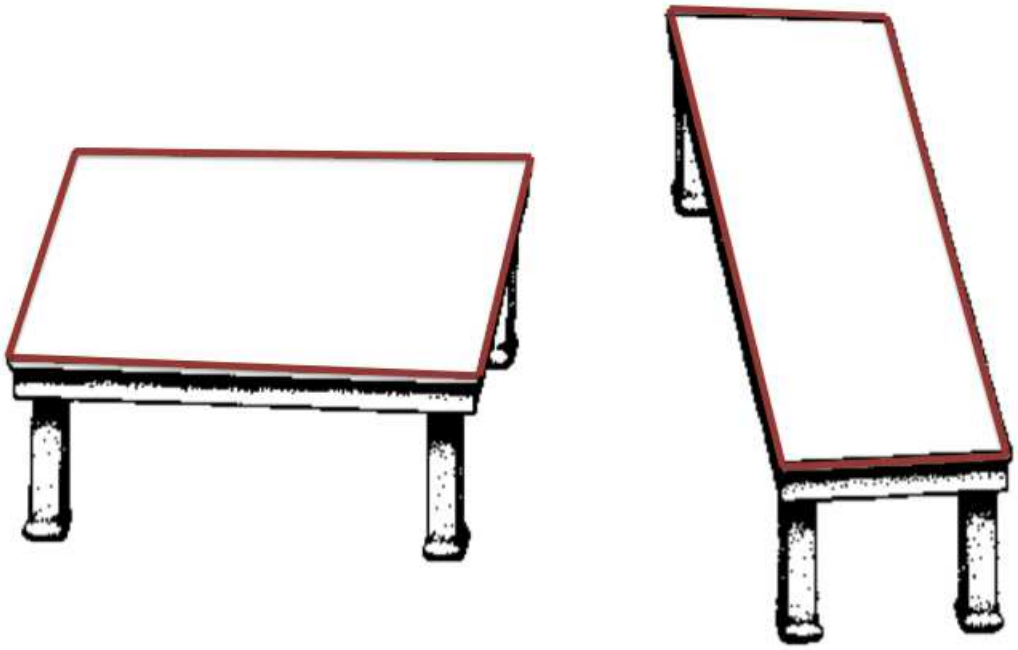
- Turning off the interpretation of "tables in space", we see two parallelograms of identical size and shape.



- See also Muller-Lyer illusion

Information vs. Representation

- The difficulty in seeing the two tabletops as simple parallelograms having the same size and shape, shows that **the internal representation in the brain is quite different from the pattern present on the retina.**



- The interpretation process in the brain is quick and automatic, and very difficult to suppress.

Unconscious Inference

- *Unconscious inference* is a cognitive principle formulated by Hermann von Helmholtz:
  - an automatic (involuntary or reflex-like) mechanism contributing to visual impressions
  - 3-D objects are automatically infered from cues present in a 2-D pattern on the retina.

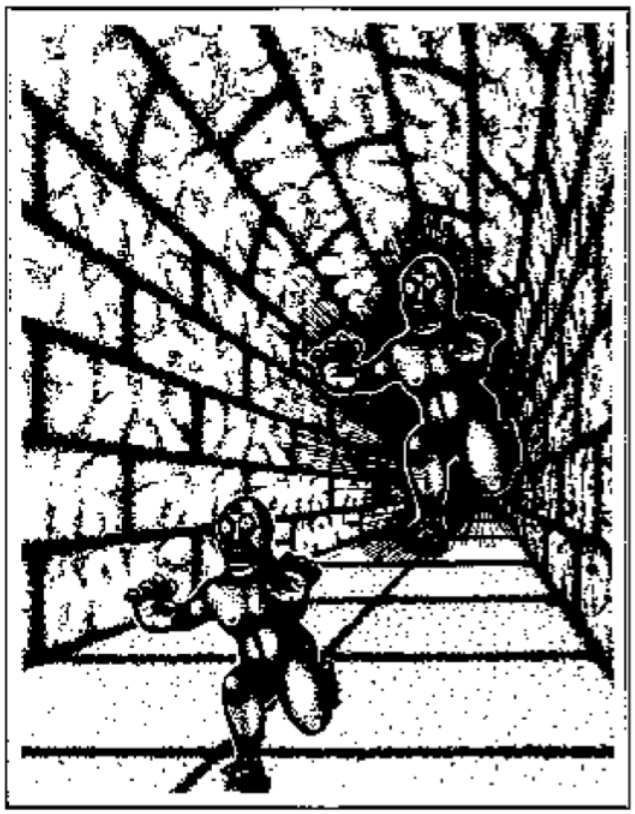


Figure 2: Monsters of same size illustrate unconscious inference.

Cues Supporting 3-D Inference

- 2-D cues supporting 3-D representation:
  - *Linear perspective*: converging lines in 2-D convey parallel lines and depth in 3-D
  - *Gradient of size*: elements of uniform texture decrease in size as they approach the horizon
  - *Aerial perspective*: objects in the far distance appear lighter and blue
  - *Binocular parallax*: each eye receives a slightly different image allowing the brain to make inferences about distance;
  - *Motion parallax*: movement on the part of the observer changes images on each retina;
- Cues support inference to 3-D interpretation but inference is *unconscious*.
  - experiments suggest we have no notion of the cues are brains are using;
  - cues can be removed without sacrificing judgment about relative distances and placements of objects.

Optical Illusions and Unconscious Inference

- Certain optical illusions are instances of unconscious inference:
  - Example by Helmholtz: sun going down behind a stationary horizon (sun is fixed; horizon moves)

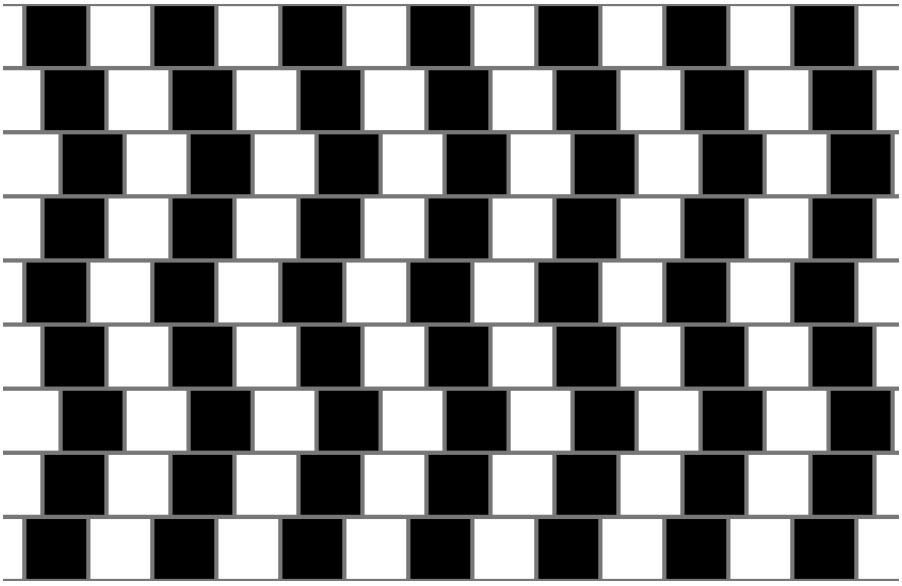


Figure 3: Cafe wall: a *distorting* illusion with parallel horizontal lines

  - interactvie cafe wall (change black to white)
  - interactvie cafe wall (more change of geometry)

Direct Perception

- James Gibson (20th century psychologist in *visual perception*) rejected *information processing* view of cognition:

  > "Information is sufficient to construct an accurate representation of disposition of objects in space."

- **Ecological psychology**: mind directly perceives environmental stimuli without additional cognitive construction or processing.
- **Direct perception (or realism)**: sensory perception is the *direct* result of information from the surrounding envionment.
  - sensory information is all that is necessary (inferences are not);
  - a "bottom-up" approach:
    - knowledge about an environment is "pieced together" from what is *directly* perceived;
    - larger subsystems are gradually created until a complete top-level system is formed;

- E.g.: a person standing in a library would see books, shelves, and other furniture:
  - superpositioning of shelves and their decreasing size provides direct information about depth and size of library;

Direct Perception vs. Unconscious Inference

- Direct perception conflicts with theories involving need of "inferences" or "beliefs" to make sense of their sensory experience.
- What about cognitive tricks (seeing something that is not really there)?
- It is suggested that *direct perception* can be reconciled with *unconscious inference* in that
  - complex computation is required to process the information coming into the sensory systems
  - most of that computation is unconscious

Size and Loudness Constancy

- The image on the retina of objects of constant size will expand and contract as the object moves closer and farther away.
- *Size constancy* allows us to perceive objects as they are, independent of their distance from us.

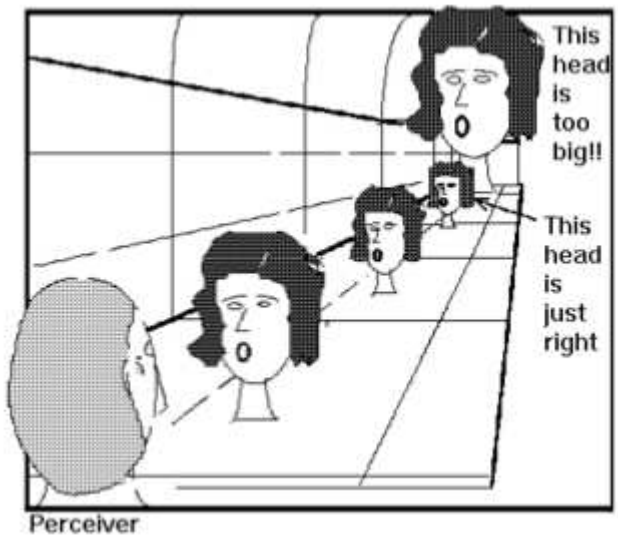


Figure 4: The head closest to the perceiver is the same size as the farthest head.

- A direct analog in the auditory domain is that sound intensity decreases with distance (inverse square law).
- *Loudness constancy* allows us to percceive an increase in distance from a source if there is a decrease in amplitude.

Intensity vs. Distance Cues

- A balloon deflating isn't necessarily perceived as moving farther away.
- Likewise, it's possible to change sound intensity without changing the source's distance.
- Cues determining whether change is in the intensity of the source or its distance from the observer:
  - **spectral balance**: increased intensity is usually accompanied by increased higher frequency components for closer sounds;
  - **reverberation**:
    1. intensity ratio of direct to reflected sound
    2. time delay between direct and reflected sound decreases with distance from source.

Spatial Inversion

- A human observer is "wired" to interpret information in its usually encountered form:
  - if a familiar pattern is transformed, even though all the information is retained, that pattern may be interpreted differently.
- Consider Rotation:

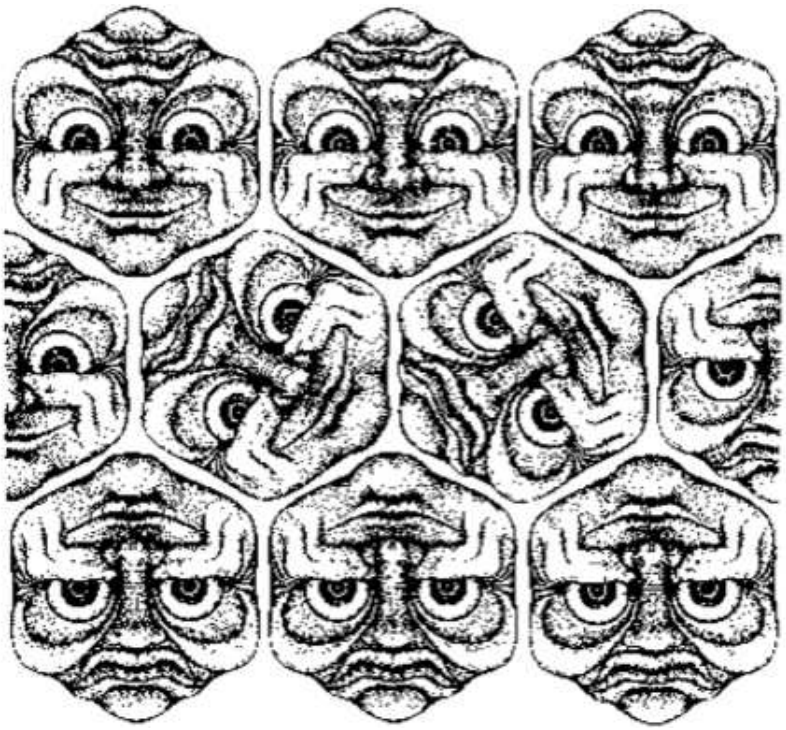


Figure 5: We are more accustomed to seeing faces right-side up, thus the upper and lower rows are perceived as being of two different faces rather than one face in two orientations.

Temporal Reversal

- An auditory analog to spatial inversion is **temporal reversal**:
  - in normal surroundings we receive direct and reflected sound;
  - echos/reverb/decay allow inference of the character of the space/source;
  - reflected sounds reach a listener *later* then direct sounds;
- It is more difficult ot deal with echos/decay preceding a signal:
  1. a resonant object produces a sound that decays exponentially over time—when played in reverse, the sound is quite different.
     - what is this instrument in this sample (played in reverse)? Click to listen
     - the original sound: Click to listen
  2. example in which reverberation precedes speech: Click to listen

Perceptual Completion

- Our perception may compensate for incomplete information coming into our sensory systems.
- Consider the disk atop a bar:

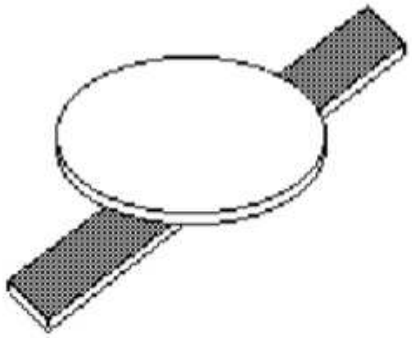


Figure 6: We would normally assume one bar instead of two beneath the disk.

Broken Bar Unexpected

- We normally assume one bar, rather than two, beneath the disk.

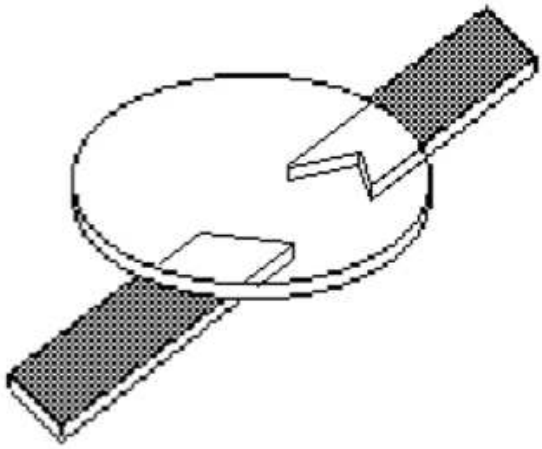


Figure 7: This result would likely surprise the observer.

Implied Triangle

- In an example by psychologist Gaetano Kanizsa, a white triangle appears located at the center of the figure (illusory contours).

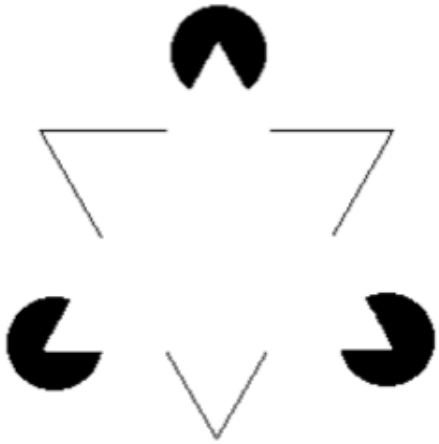


Figure 8: The suggestion is a triangle lying on objects.

- Though no such triangle actually exists, the presence of the triangle is the most likely explanation in the external world.

Auditory Perception Completion I

- The auditory analog is demonstrated by Al Bregman with sinusoids and noise.
- Part of signal A is replaced with silence then with signal B.

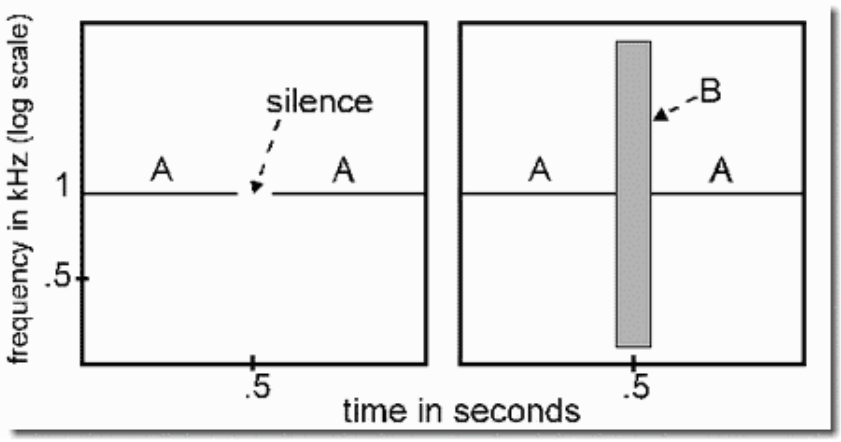


Figure 9: Replacing a gap with signal B can create preception of completion (continuity).

- If signal B is loud enough, signal A appears to continue behind it.
- Click to listen
- This effect occurs when neural activity during B includes activity very similar to what would normally occur during A.

Auditory Completion II

- In another experiment by Al Bregmen, the signals are swept up and down in frequency.

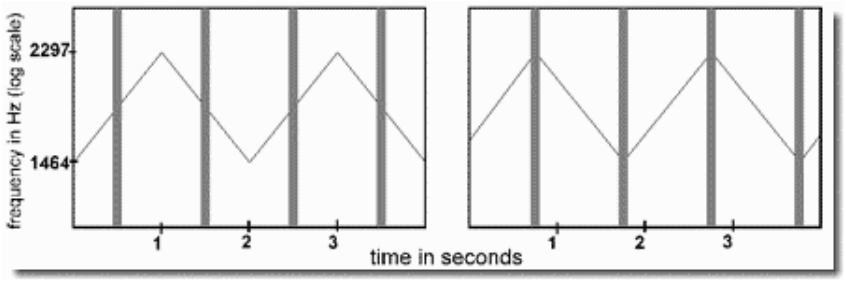
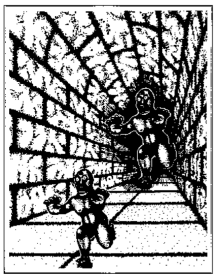


Figure 10: Discontinuity in the middle of ascending and descending legs or at peaks and valleys.

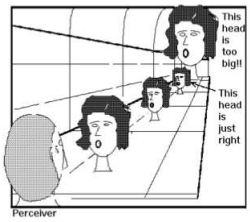
- Continuity is not dependent on the signal being in a steady state.
- Click to listen

Summary

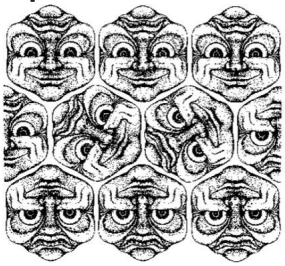
- Fundamental Principles of Perception:
  - Unconscious Inference vs. Direct Perception



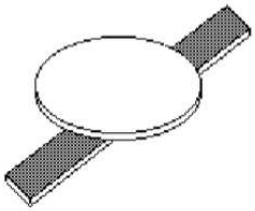
  - Size and Loudness Constancy



  - Spatial and Temporal Inversion



  - Perceptual Completion



Gestalt Psychology

- *Gestalt* "shape, form"
- Gestalt psychology: the mind considers objects in their entirety before, or in parallel with, perception of their individual parts.

> "The whole is other than the sum of its parts".

- Gestalt psychologists sought to understand the perception of whole forms rather than just a collection of simpler elements (points, lines, curves, etc.)
- Max Wertheimer, principal founder of Gestalt psychology, formulated **Gestalt principles of grouping** which are used by the brain when parsing sensory input into objects in the world.

The Gestalt Grouping Principles

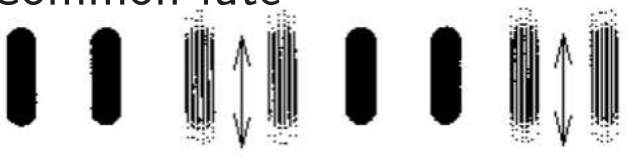
- Gestalt principles are based on Helmholtz's concept of unconscious inference:
  - Proximity

  - Similarity

  - Symmetry

  - Continuity

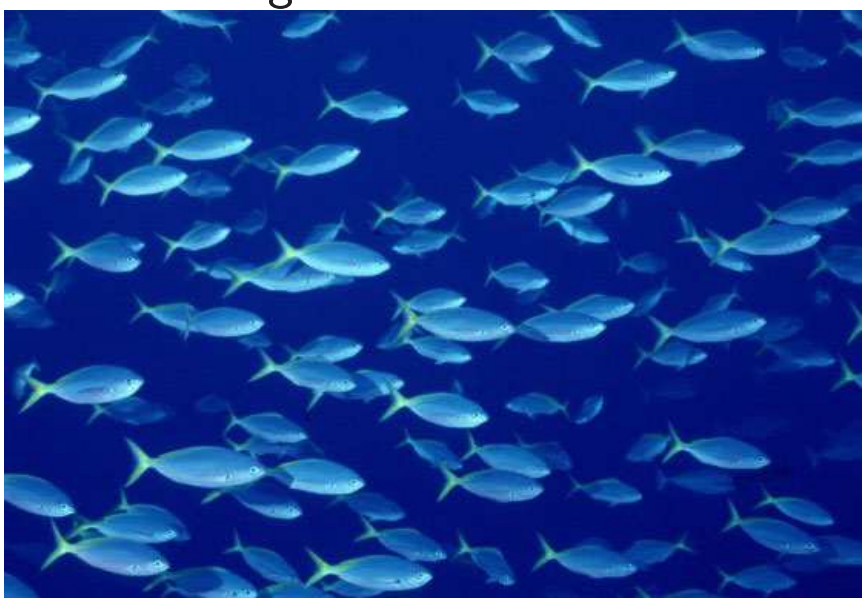
  - Common fate



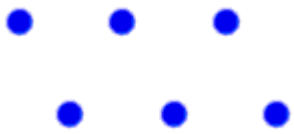
- The first 4 are *weaker* than the much stronger "common fate".

Common Fate

- In the world, it is extremely improbable that two things move in a perfectly correlated way unless they are in some way connected.
- When visual elements are moving together, they are perceived as a single Gestalt.



- Animation: Click to watch



Audio Common Fate

- Isolating a sound source involves grouping harmonics or partials making up the sound.
- Since harmonics/partials tend to move together, in both frequency and amplitude, grouping, and isolation, is done by the principle of common fate.
- Examples of auditory common fate include:
  - common onset time;
  - common amplitude and frequency modulation: partials tend to move in ensemble, in both amplitude and frequency;
- Examples:
  - isolating the voice of a speaker;
  - isolating a solo instrument in an ensemble.