Radiography CPD activity for 2015

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**TOPIC:**
NOW YOU SEE IT, NOW YOU DON’T: VISUAL ILLUSIONS IN RADIOLOGY

Approved for two (2) Clinical Continuing Educational Units
Visual illusions are distortions, alterations, or alternatives in the appearance of reality that result primarily from the sensory and perceptual processing mechanisms of the human visual system. These illusions are common phenomena in radiology, and it is important to understand them because they can create the illusion of disease, leading to incorrect image interpretation. Visual illusions in radiology can be organized according to the point in the visual system at which they emerge. Illusions of sensation, including Mach bands and background effect, are “lower-order” visual phenomena that occur as the eye and brain translate light into neural activity. Illusions of perception, such as ambiguous figures and distortion, occur in “higher-order” brain structures that are responsible for coalescing sensory input into a mental image interpreted by the mind. Illusions of image formation (eg, parallax), as the name implies, result from the way images are generated. Some visual illusions occur with all modalities, whereas others tend to be modality specific. The authors discuss a variety of visual illusions, describing their underlying psychologic and neuroscientific basis and demonstrating their relevance to radiology. A thorough understanding of visual illusions in radiology enhances diagnostic accuracy by minimizing the risk of mistaking illusions for disease.

Introduction

From a mirage to Houdini, from the Necker cube to a reflection—visual illusions are everywhere, and the field of radiology is no exception. Visual illusions are distortions, alterations, or alternatives in the appearance of reality that result primarily from the sensory and perceptual processing mechanisms of the human visual system. But perhaps the best way to define visual illusions is with use of examples. What do you see in Figure 1a? Is it the profile of a young woman in a fur coat wearing a black necklace (Fig 1b)? Or perhaps an older woman with a jagged nose (the cheek of the younger woman) and pursed lips (the necklace of the younger woman) (Fig 1c)? This image, “Mother or Wife?” (1), is a classic example of an ambiguous figure, a visual illusion resulting in multiple (and, in this case, equally correct) interpretations of reality. Ambiguous figures are common in radiology as well. The ultrasonographic (US) image in Figure 1d is initially confusing. What are we looking at? A bird? A plane? Additional context (Fig 1e) reveals that this ambiguous finding is actually the face of a fetus in utero.
Figure 2. Categorization of visual illusions in radiology. Schematic shows that image formation, sensation, and perception are the three basic steps involved in the creation and interpretation of medical images, and that specific artifacts occur at each point in the process. Illusions of image formation include modality-specific artifacts and parallax; those of sensation include Mach bands and background effect; and those of perception include ambiguous figures, fictional illusions, distortion, and paradoxical figures.

Figure 1. (a–c) “Mother or Wife?” (a), a classic example of an ambiguous figure in the form of a visual illusion, can be interpreted as either a young woman (b) or an old woman (c). (d) Ambiguous US image, whose lack of context makes the nature and location of the structure of interest uncertain; it could be one of several body parts. (e) US image with additional context reveals that the ambiguous figure is the face of a fetus from an obstetric US study.
Figure 3. Drawings illustrate the basic concepts of the visual system. (a) Light incident on the retina is converted into electrical impulses by photoreceptors and bipolar neurons (1). Impulses are transmitted via the optic nerve (2) and the lateral geniculate nucleus (3) to the visual cortex (4), which is responsible for complex visual processing. (b) Upon reaching the visual cortex, impulses are divided into dorsal and ventral streams. The dorsal stream (5) is typically referred to as the where-how pathway and mainly consists of the posterior parietal cortex. The ventral stream (6) is also known as the what pathway and mainly consists of the inferior temporal cortex.

The term visual illusion is an umbrella term that describes a number of phenomena with a common theme: artifacts and oddities in the technique by which images are generated or in the method by which they are processed in the brain (Fig 2).

Visual illusions in radiology can be organized according to the point in the visual system at which they emerge and include illusions of sensation, perception, and image formation (artifact).

Illusions of sensation, including Mach bands and background effect, are “lower-order” visual phenomena that occur as the eye and brain translate light into neural activity. Illusions of perception, including ambiguous figures, fictional illusions, paradoxical illusions, and distortions, occur in “higher-order” brain structures that form sensation into perception, which is then interpreted by the observer. Illusions of image formation, such as parallax, result from the way images are generated and occur with all modalities.

Visual illusions occur frequently in radiology with all modalities and in all anatomic regions. They are important because they can create the illusion of disease, leading to both false-positive and false-negative findings in the interpretation of images. A basic understanding of what visual illusions are, why they occur, and how they apply to radiology is helpful in avoiding the pitfalls in image interpretation that can arise from visual illusions.

In this article, we discuss the three kinds of illusions and illustrate their relevance to radiology with examples taken from cases at our institution.

**Illusions of Sensation**

Visual sensation is the process of converting light incident on the retina into neural activity and involves both the eye and more primitive (lower-order) parts of the central nervous system. Light incident on the retina is converted into electrical impulses by specialized photoreceptors and bipolar neurons, which in turn activate neurons in the optic nerve. The optic nerve transmits the neural activity from each hemifield (left and right) to the contralateral side of the brain via the optic chiasm (Fig 3a).

Activity in the optic nerve is preprocessed by the lateral geniculate nucleus, a part of the thalamus that contains two major groups of specialized cells responding to fundamental features of an image, including motion, depth, form, and color. This preprocessed information is then sent...
to the occipital cortex, which is divided into five regions of increasing visual complexity (V1–V5). Neurons in the striate (V1) and prestriate (V2) cortices respond to specific spatial orientations and colors. From this point, neuronal impulses are sent to the V3–V5 regions of the occipital cortex. These regions are organized into two major functional pathways: dorsal and ventral. The dorsal or “where-how” pathway primarily involves the posterior parietal cortex and helps identify the location and movement of objects in space. The ventral or “what” pathway primarily involves the inferior temporal cortex and extracts information about object form and color (Fig 3b) (2). Both pathways communicate with other areas of the brain, such as the prefrontal cortex, to interpret the sensory information received during the process of perception.

Mach bands and background effect are two examples of illusions of sensation that commonly occur in radiology.

**Mach Bands**

Mach bands are apparent bright and dark lines that occur at the border between objects with different optical densities, contrast levels, or luminances (Fig 4) (3). This illusion is a form of edge enhancement created by lateral inhibition of bipolar neurons in the retina by horizontal cells. When the transduced light signal reaches a bipolar neuron, neighboring bipolar cells are simultaneously inhibited, either slightly increasing (positive Mach band) or decreasing (negative Mach band) their neural activity in response to light. The result is an accentuation of the border between objects with different light intensities (optical densities).

Mach bands are a common occurrence at radiography (Fig 5). They are helpful in demarcating the boundaries of anatomic structures with different optical densities on radiographs, such as the lungs and mediastinum, the mediastinum and trachea, and the abdominal contents (eg, bowel and psoas muscle) and the adjacent mesentery or retroperitoneum. Mach bands can also provide useful diagnostic information. For example, a dark outline around a smoothly margined breast mass on mammograms, also known as the “halo sign” (representing a negative Mach band between fat and soft tissue), strongly suggests a benign breast mass. A positive Mach band between central and peripheral regions of a lung nodule indicates cavitation, and a positive Mach band between a pleural effusion and lung parenchyma helps delineate the extent of a layering pleural effusion. However, Mach bands can also be mistaken for disease. A skin fold or overlap between the posterior atlas and the dens can create a negative Mach band passing through the base of the dens, which simulates a fracture (Fig 5a).

Extension of the Mach band beyond the contour of the dens, absence of lucency on the lateral view, and absence of secondary signs of cervical spine trauma (eg, soft-tissue swelling) are helpful
Figure 5. Mach bands. (a) Axial radiograph of the oral cavity shows a negative Mach band simulating a type 2 fracture of the dens (arrow). (b) Frontal chest radiograph shows a Mach band between the lung and the left heart border simulating pneumomediastinum (arrows). (c) Oblique radiograph of the knee shows a Mach band between the tibia and fibula that could be mistaken for a fracture (arrows). (d) Frontal chest radiograph shows a negative Mach band (box) that suggests the presence of a skin fold simulating pneumothorax. (e) Frontal chest radiograph obtained after chest tube removal helps confirm the finding suggested in d.

in distinguishing Mach bands from true fractures. Other pseudofractures can be found in the articular pillar due to a skin fold, in the posterior aspect of a vertebral body due to overlap of the transverse process, in the femoral neck due to acetabular osteophytes, or in the posterior elements of the lower lumbar spine due to overlap of the iliac crest on the lateral view (4). Mach bands can also occur between the mediastinum and lung parenchyma on frontal chest radiographs and can occasionally be mistaken for pneumomediastinum or pneumopericardium (Fig 5b). The presence of a negative Mach band and the absence of a pleural line between an apical area of lucency and lung parenchyma suggest pseudopneumothorax caused by a skin fold (Fig 5d). At angiography, crossing vessels can produce a Mach band that may simulate a dissection (4–6).
Background Effect
Another type of sensory visual illusion is background effect. The term background effect refers to the modulation of either an object’s optical density (at radiography) or gray level (at computed tomography [CT] or magnetic resonance [MR] imaging, with differences in attenuation or signal intensity represented by different shades of gray) caused by changes in the optical density or gray level of its background. In Figure 6a, the two large squares have backgrounds with dramatically different gray levels. The two small squares appear to have different gray levels, with the left square appearing darker than the one on the right. However, when the background is eliminated (Fig 6b), it is apparent that the small squares have the same gray levels. Background effect and Mach bands are similar in that they both involve lateral inhibition. However, background effect involves changes in the optical density or gray level of an area, whereas Mach bands occur as lines at object boundaries.

Background density illusions are often encountered at CT and MR imaging. They arise whenever adjacent objects with similar attenuation or signal intensity become more conspicuous as the background attenuation or signal intensity changes (eg, with the use of contrast material). Applications of the background effect include the use of triple phase CT to characterize hepatic, pancreatic, and renal masses; dynamic imaging for the workup of adrenal adenomas; and the administration of contrast material to better delineate abscesses, lymph nodes, and bowel.

Figure 7 illustrates how background effect can be used to better visualize a renal cyst. Perceived differences in attenuation at CT can also be accentuated by background effect. The use of postprocessing techniques such as dynamic windowing can be thought of as an extension of the background effect concept. Windowing modifies the relationship between the signal intensity and gray scale by changing the range (width) and midpoint (center) of the lookup table used to assign shades of gray to signal intensity values. Optimal windowing maximizes the gray-level contrast between the object of interest and its background. In Figure 8, for example, a subarachnoid hemorrhage is barely visible on a lighter brain background but becomes clear when the background is darkened by changing the center of the window. Background density effects also occur in radiography due to differences in optical density. The broad hyperlucent zone around some breast cancers (7) is thought
Figure 7. Background effect. (a) CT image shows a renal cyst (arrow) with attenuation similar to that of nonenhancing renal parenchyma. (b) On a nephrogenic phase contrast material–enhanced CT image, the gray level of the background renal parenchyma is increased, making the lesion (arrow) appear darker and consequently more conspicuous.

Figure 8. Dynamic windowing and background effect. (a) On a brain CT image, a subarachnoid hemorrhage in the left frontal lobe (circled) is inconspicuous, since the higher gray level of the background brain parenchyma darkens the focus of hemorrhage. (b) On a brain CT image obtained with a lower window center, the gray level of the brain parenchyma is darkened because of the background effect, thereby increasing the conspicuity of subarachnoid blood.

to be the result of background effect, as is the accentuated border between a dense pedicle and pars interarticularis in the lower lumbar spine that can simulate spondylolysis.

Illusions of Perception
Perception is a poorly understood process that broadly concerns the interpretation of visual reality after it has been formed by sensation. There is no clear line separating perception from sensation; rather, the processes operate in synchrony and along a continuum.

The mechanism of perception is the subject of a long-standing debate in cognitive science, and a detailed discussion is beyond the scope of this article. However, perception is generally thought to involve two mechanisms: “bottom-up” and “top-down” processing. In bottom-up processing (Fig 9a), the image is assembled in small modular steps, starting from basic sensory processes (in the lateral geniculate nucleus, V1, and V2) and gradually incorporating cognitive processes,
with perception being the final result. The basic building blocks of perception are called geons (8) and consist of a series of primitive shapes. These geons are systematically combined to produce an object, which is then matched to a database of objects in the visual memory, with a match resulting in perception. Although this bottom-up processing model is oversimplified, it explains why experience is so important in the interpretation of radiographs: Familiarity with multiple examples of the same disease process creates a more extensive database of geons, thereby increasing the chances of a match with a novel image and making accurate perception more likely.

Top-down processing (Fig 9b) occurs when cognitive factors such as learning, memory, attention, and expectation shape the perceptual process from the beginning. According to the top-down theory, images are not processed in a modular fashion, but rather are perceived holistically as more than the sum of their parts. The top-down approach accounts for how it is possible to identify an object on an image even if part of the object is not visible (Fig 9b). Gestalt psychologists are the leading proponents of top-down processing and argue that spatial relationships between objects (e.g., symmetry, proximity, closure) are the key determinants of perception.

The perceptual system likely incorporates both bottom-up and top-down processing to varying degrees. According to the model developed by Gregory (9), perception begins with the bottom-up processing of sensation into image features, with the salience of each feature determined by top-down processes influenced by experience, expectation, and attention. Together, bottom-up and top-down processing generate a hypothesis about the image that is matched to past experience, resulting in perception.

The neural basis for perception is poorly understood but likely involves the higher-order V3–V5 regions of the visual cortex organized into dorsal (where-how) and ventral (what) pathways. For example, there is evidence that neurons in these higher-order regions selectively respond to specific complex visual forms, such as faces, even particular faces such as that of a grandmother (or, in the case of a radiologist, Aunt Minnie) (10). Perception then occurs as this higher-order–processed visual information is sent to secondary-association areas (e.g., the inferior temporal lobe), where it interacts with information from cortical regions involved in cognition, including the prefrontal cortex (associated with expectation and judgment), the cingulate cortex (associated with attention), and the hippocampus (associated with the consolidation of visual memories). Thus, perception occurs at the intersection of sensation and cognition.

The operations of the perceptual system can alter the appearance of reality by introducing perceptual illusions. Gregory (9) classifies perceptual illusions into four broad categories—ambiguous figures, fictional illusions, paradoxical illusions, and distortions—all of which can occur in radiology.
Figure 10. Ambiguous image shows either the silhouettes of two faces or a vase, depending on the observer’s perspective. The illusion dynamically yet transiently shifts from the silhouettes to the vase.

Figure 11. Ambiguous radiologic figure. (a) US image shows a focal prominence of the renal cortex (arrow) that could be interpreted as an exogenous renal mass or a normal anatomic variant (column of Bertin). (b) Follow-up CT image reveals that the mass (black arrow) is isoattenuating relative to the adjacent renal parenchyma (white arrow), a finding consistent with variant anatomy.

Ambiguous Figures
Ambiguous figures result in multiple perceptual interpretations, each of which may be correct. The classic ambiguous figure “Mother or Wife?” (Fig 1a) was mentioned earlier. The “faces or vase” figure (Fig 10) is another example. Ambiguous figures provide strong evidence for a top-down component to perceptual processing, since the same sensory information can be perceived in different ways even with small shifts in attention. Ambiguous figures are an example of bistable perception, whereby one’s attention to an object or scene shifts dynamically yet transiently from one perspective to another (11).

The Gestalt principle of figure-ground plays a central role in the perception of ambiguous figures. Most images have a foreground and a background, and choosing which part of the image will serve as figure-foreground and which as background can lead to very different interpretations. If the white region in Figure 10 is chosen as the background, the black regions become the foreground, and the image is perceived as two silhouettes. However, if the black regions are considered to be the background, the white area becomes the foreground, and the image is seen as a vase or chalice. Generally, foregrounds tend to be formed by objects that are brighter and more central, although experience (whether the object has been seen previously), mood (happy or sad), attention (the region of the image that is inspected first), and other top-down processes make important contributions. Evidence suggests that the fusiform gyrus, posterior intraparietal
fat and ignored completely. However, if the fatty region between the stomach and duodenum is considered to be the foreground, it becomes the pancreas with massive fatty replacement due to cystic fibrosis (Fig 12b). Examples of the impact of foreground and background decisions on the interpretation of ambiguous figures are seen with all modalities, even radiography (Fig 12c).

Ambiguous figures—images that lend themselves to more than one interpretation—are common in radiology (Figs 11, 12), and the choice of which perceptual alternative to favor can have a significant impact on diagnosis and subsequent patient management.

As in the graphic arts, the choice of foreground and background can result in ambiguous figures in radiology. In the abdomen, organ parenchyma generally forms the foreground, with mesentery and peritoneum forming the background. In the abdominal CT image in Figure 12a, the low-attenuation region between the stomach and the third portion of the duodenum could be interpreted as background mesenteric cortex, ventral prefrontal cortex, and frontal eye fields play an important role in the perception of ambiguous figures (12).

Figure 12. Ambiguous radiologic figures: importance of foreground and background designations. (a) Abdominal CT image shows a hypoattenuating mass in the upper quadrant at the midline (circled) that could be mistaken for mesentery if considered part of the background. (b) Abdominal CT image shows how changing the visual paradigm by considering the abnormality as part of the foreground is critical in making the correct diagnosis, namely, fatty infiltration of the pancreas (circled). (c) Frontal chest radiograph illustrates how, if the scapula is perceived as foreground and the ribs as background, the circumscribed area of lucency (white arrow) might be interpreted as a lytic lesion of the scapula. If, on the other hand, the scapula is perceived as background and the rib cage as foreground, it becomes apparent that the lucent area is in fact normal lung parenchyma adjacent to a bony bridge between the ribs (black arrow).
Fictional Illusions

The term fictional illusion refers to the apparent presence of an object on an image when no object is actually present. Subjective contours and questionable lesions are two kinds of fictional illusions frequently encountered in radiology.

Subjective Contours.—Subjective contours are fictional illusions that produce false geometric shapes by extending lines and boundaries in the mind’s eye (4,13). This phenomenon can be explained using the concept of perceptual grouping along with figure and ground. Perceptual grouping is a highly context-driven means by which the brain organizes objects and their backgrounds according to texture and depth cues (14). For example, in the fictional illusion known as the Kanizsa triangle (Fig 13), the positioning of black three-quarter circles in the “correct” orientation results in the appearance of a white triangle, even though none is present (15). This fictional triangle is suggested by the partial contours at its apices and edges formed by the black circles (16); however, if one of the circles is removed, the illusion disappears (Fig 13). The neurobiology underlying this illusion involves interconnections between the lateral geniculate nucleus, V1, and V2. The Kanizsa triangle demonstrates three of the four cardinal features of subjective contours: the objects they create are without physical basis, and the area bounded by the subjective contour appears both brighter than the background and superimposed on top of it. Subjective contours may also be generated in the absence of straight lines.

According to Gestalt theory, two visual principles—completeness and continuity—account for the occurrence of subjective contours (17). Completeness is the natural tendency of the human visual system to make sense of the world by organizing space into objects whenever possible. As such, the mind seeks to complete shapes when they are partly suggested by lines. Continuity is the tendency to prefer smooth and continuous boundaries over irregular or discontinuous ones, such that overlapping lines will be seen as a continuous structure even when they are separate. The perceptual system is, therefore, inclined to see continuous smooth lines even if they are interrupted by subtle distortions (continuity) and to form an object when a part of it is only suggested (completeness), both of which processes result in the creation of subjective contours.

Radiographs are the major source of subjective contours in medical imaging because of the poor contrast resolution that results from the projection of three-dimensional anatomy onto a two-dimensional film. Subjective contours caused by the need for completeness (18) create pseudolesions that can be mistaken for real pathologic conditions (Fig 14). Pseudonodules of the lung...
can be produced by the costochondral junction, osteophytes, or stool. In addition, continuity—the tendency to see continuous smooth contours despite subtle irregularities—can lead to a false-negative finding, as in the case of a subtle buckle fracture of the radius (Fig 14c, 14d).

Hence, it is important to be aware of subjective contours created by superimposed anatomy and experience in the interpretation of radiographs because they may result in mistaking pseudolesions for real disease entities or in dismissing contour irregularities as normal variants.

**Questionable Lesions.**—Questionable lesions are a second kind of fictional illusion and suggest real disease when none is actually present. As such, questionable lesions represent a false-positive finding. Unlike subjective contour, ques-
Questionable lesions are found with all imaging modalities and have a variety of causes ranging from technical artifacts to normal variants (Fig 15). In some situations, it may be impossible to distinguish questionable lesions from early or subtle manifestations of real disease; in other cases, the context or findings may be more suggestive of an artifact. The decision to “call” questionable lesions is interpreter dependent. Readers with high sensitivity will necessarily call more questionable lesions, with tradeoffs in their specificity. Either way, the occurrence of fictional lesions, especially those due to technical artifacts, has the potential to create errors in image interpretation.

**Paradoxic Illusions**

Paradoxic illusions are a third type of perceptual illusion, but many could also be classified as illusions of technique. Paradoxic illusions are descriptive of images that are impossible or self-contradictory, generally involving unexpected relationships between objects that defy physical laws or rational explanation. A well-known example is M.C. Escher’s “Waterfall,” an image that shows water falling from a great height after flowing uphill. Paradoxical images in the art world are limited only by canvas and imagination, whereas similar images in medical imaging are more limited in that the body obeys the laws of physics. Although they rarely constitute a diagnostic dilemma, paradoxic images are an interesting category of illusions and may be helpful in conveying the bizarre appearance of an image to the referring clinician (Fig 16).
Distortions
Distortions are exaggerations in the scale or dimension of one object created by surrounding objects in specific contexts. They likely result from incorrect perceptual assumptions about the spatial relationships between objects (19). An example is the Müller-Lyer illusion, in which two lines of equal length are made to appear shorter or longer depending on whether the arrows at their ends point inward or outward (20). In another example, the Titchener circle illusion, a central circle is made to appear larger if surrounded by many smaller circles (Fig 17).

Because distortions require specific geometric contexts, they are not commonly seen in the nonlinear world of radiology. However, they may have implications for the measurement of lesions on images. For example, lesions with the same dimensions may appear longer than they are wide. Confluent lymphadenopathy around a vessel may make it look smaller compared with the contralateral side, not because of compression but because of the Titchener visual illusion.

Illusions of Image Formation
Visual illusions can also result from technical effects in the production of medical images and occur with all imaging modalities. Some artifacts are specific to one modality, whereas others are common to several modalities. Although some of these artifacts create illusions that overlap with other categories (eg, fictional illusions), thereby blurring the distinction between categories, it is helpful to consider illusions of image formation separately because of their common origin in the process of image formation rather than the brain.

Some illusions of image formation can be useful diagnostically, whereas others may limit the diagnostic yield. One example of a modality-specific artifact is the parallax effect on radiographs. Parallax is an apparent exaggeration of the relative position of two objects when viewed along two different lines of sight. Given the two-dimensional nature of radiographs, parallax is an important principle in localizing objects within the body. On the basis of a single frontal view, it is impossible to tell the anteroposterior location of an abnormality. However, a second view from a different perspective can be used to localize the object. Among other uses, parallax is helpful in triangulating breast lesions prior to stereotactic biopsy, localizing foreign bodies, identifying malpositioned medical devices (eg, gastrostomy

![Figure 17. Titchener circle illusion shows how distortions can arise within specific geometric contexts. The central circles in the two groups are the same size. However, they appear to be different sizes due to the context established by the surrounding circles. The smaller surrounding circles make the central circle on the left appear larger than the central circle on the right.](image-url)
tubes, catheters, and defibrillators), and confirming and localizing disease entities (eg, fractures, pneumonia, and neoplasms). However, parallax can also distort or exaggerate the appearance of normal anatomy on radiographs due to divergence of the x-ray beam from its point of origin at the extremes of the image. In Figure 18, the L1-2 disk space at the periphery of the image appears narrower than the L4-5 space in the center of the image, a distortion due to parallax that might be mistaken for disk disease.

Specific artifacts occur with all imaging modalities. Like parallax, some of these artifacts demonstrate a “love-hate” relationship with diagnosis—at times being helpful in the characterization and localization of disease, and at other times limiting the diagnostic yield by degrading image quality or by masquerading as real disease. Examples of this hybrid character of technical artifacts include (a) chemical shift and zipper artifacts at MR imaging, and (b) ring down artifact and shadowing at US. However, many artifacts only lower the diagnostic yield, including beam hardening at CT, a defunct photomultiplier tube when imaging with a gamma camera at nuclear scintigraphy, and refraction at US. Other artifacts are common to several modalities, such as motion artifact, partial volume averaging, quantum mottle, and aliasing.

**Conclusions**

Visual illusions are interesting phenomena that are directly relevant to a visual specialty such as radiology. They represent alterations in the appearance of reality due to the processes of image formation and interpretation, and they can be broadly categorized according to the steps in the image interpretation process (formation, sensation, perception) that are most likely to produce them. Illusions of image formation are technical artifacts that result from the physics of image formation. Some are modality specific, whereas others are common to many modalities; some are helpful, but many limit the diagnostic yield. Illusions of image sensation (eg, Mach bands and background effect) occur as light from the image is translated into brain activity. Illusions of perception occur as the brain forms and interprets the image and include ambiguous figures, fictional illusions, paradoxical illusions, and distortions. Although these categories overlap and many examples fit into more than one category (eg, technical artifacts and paradoxical illusions), the framework provides a conceptual basis for understanding illusions and their origins.

Understanding visual illusions is important for three reasons. First, visual illusions can degrade image quality or be mistaken for real disease, resulting in misinterpretation. Second, they can at times be helpful in making a diagnosis (eg, the halo effect at mammography, parallax at radiography, or chemical shift effect at MR imaging).
Third, a knowledge of visual illusions provides justification and specific language for describing a distortion on an image (eg, “This paramediastinal lucency represents a Mach band and not a pneumothorax”). Just as a basic understanding of cars makes them easier to drive, so understanding the basic principles of sensation and perception that underlie vision and visual illusions will benefit the radiologist in his or her daily practice.

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References
Question 1: Which one of the following occurs in “higher-order” brain structures?

A: Illusions of sensation  
B: Illusions of perception  
C: Illusions of image formation  

Question 2: Which of the following are classified as an illusion of image formation?

A: Mach bands  
B: Ambiguous figures  
C: Parallax  
D: Fictional illusions  
E: Modality specific artifacts  

Question 3: Which of the following are TRUE with regard to visual illusions?

A: Visual illusions occur frequently  
B: Visual illusions occur only in certain modalities and certain body regions  
C: Visual illusions can create the illusion of disease  
D: Visual illusions can lead to both false-negative and false-positive findings in the interpretation of images  

Question 4: With regard to illusions of sensation, which functional pathway primarily involves the inferior temporal cortex and extracts information about object form and colour?

A: The dorsal pathway  
B: Ventral pathway  

Question 5: Which of the following are FALSE with regard to Mach bands?

A: Mach bands are a common occurrence at radiography  
B: They are not of much use in demarcating the boundaries of anatomic structures with different optical densities on radiographs  
C: Mach bands can produce useful diagnostic information, such as a ‘halo sign’, which strongly suggests a benign breast mass  
D: A positive Mach band between a pleural effusion and lung parenchyma helps delineate the extent of a layering pleural effusion  
E: Mach bands cannot be mistaken for disease  

Question 6: Is it TRUE or FALSE that the presence of a negative Mach band and the absence of a pleural line between an apical area of lucency and lung parenchyma suggest pseudopneumothorax caused by a skin fold?

A: TRUE  
B: FALSE  

Question 7: The sensory visual illusion, background effect, refers in which modality to the modulation of an object’s gray level?

A: MR  
B: Radiography  
C: CT  
D: Ultrasonography
**Question 8:** Which of the following are applications of the background effect?

A: The use of triple phase CT to characterize hepatic, pancreatic, and renal masses
B: The administration of contrast material to better delineate abscesses, lymph nodes and bowel
C: The use of dynamic imaging for the workup of adrenal adenomas
D: A, B and C

**Question 9:** Is it TRUE or FALSE that optimal windowing minimizes the gray-level contrast between the object of interest and its background?

A: TRUE
B: FALSE

**Question 10:** Can the accentuated border between a dense pedicle and pars interarticularis in the lower lumbar spine, as a result of background effect, simulate spondylolysis?

A: YES
B: NO

**Question 11:** Which of the following statements are TRUE with regard to illusions of perception?

A: Perception is a process that concerns the interpretation of visual reality before it has been formed by sensation
B: There is a clear line separating perception from sensation
C: The process of perception operates in synchrony and along a continuum
D: Perception is a well understood process
E: Perception is generally thought to involve two mechanisms: “bottom-up” and “top-down” processing

**Question 12:** According to which one of the following theories are images perceived holistically as more than the sum of their parts?

A: The “bottom-up” theory
B: The “top-down” theory

**Question 13:** Which one of the following is associated with the consolidation of visual memories?

A: The cingulate cortex
B: The prefrontal cortex
C: The visual cortex
D: The hippocampus

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**Question 14:** Which one of the following categories of perceptual illusion, as classified by Gregory, can occur in radiology?

A: Ambiguous figures, paradoxic illusions, fictional illusions, and distortions
B: Only distortions
C: Paradoxic illusions, fictional illusions and distortions
D: Ambiguous figures and fictional illusions

**Question 15:** Is it TRUE or FALSE that ambiguous figures result in multiple perceptual interpretations, of which only one may be correct?

A: TRUE
B: FALSE

**Question 16:** Is it TRUE that ambiguous figures are common in radiology and the choice of which perceptual alternative to favor can have a significant impact on diagnosis and subsequent patient management?

A: YES
B: NO

**Question 17:** Can subjective contours caused by the need for completeness, create pseudolesions that can be mistaken for real pathologic conditions?

A: YES
B: NO

**Question 18:** Questionable lesions represent which of the following?

A: A false-negative finding
B: A false-positive finding

**Question 19:** Which illusion makes a central circle appear larger if surrounded by many smaller circles?

A: The Müller-Lyer illusion
B: The Titchener circular illusion

**Question 20:** Among other diagnostic uses, parallax in radiography is helpful in which of the following?

A: Triangulating breast lesions prior to stereotactic biopsy
B: Localizing foreign bodies
C: Identifying malpositioned medical devices
D: Confirming and localizing disease entities
E: All of the above
ANSWER FORM
(If your personal details have not changed, only complete the sections marked with an asterisk)

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A11 (15)
NOW YOU SEE IT, NOW YOU DON’T: VISUAL ILLUSIONS IN RADIOLOGY

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I hereby declare that the completion of this document is my own effort without any assistance.

Signed: ____________________________ Date: ____________________

Please rate the article:

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<th>GOOD</th>
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FAX TO 0866144200 OR 012 653 - 2073 AFTER COMPLETION
(YOU WILL RECEIVE A CONFIRMATION OF RECEIPT SMS WITHIN 12-24 HOURS)

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(70% PASS RATE)

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