*On the Uses of Make-Perceive**

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Abstract: Human beings have the ability to 'augment' reality by superimposing mental imagery on the visually perceived scene. For example, when deciding how to arrange furniture in a new home, one might project the image of an armchair into an empty corner or the image of a painting onto a wall. The experience of noticing a constellation in the sky at night is also perceptual-imaginative amalgam: it involves both seeing the stars in the constellation and imagining the lines that connect them at the same time. I here refer to such hybrid experiences – involving both a bottom-up, externally generated component and a top-down, internally generated component – as *make-perceive* (Briscoe 2008, 2011).

My discussion in this paper has two parts. In the first part, I show that make-perceive enables human beings to solve certain problems and pursue certain projects more effectively than bottom-up perceiving or top-down visualization alone. To this end, the skillful use of projected mental imagery is surveyed in a variety of contexts, including action planning, the interpretation of static mechanical diagrams, and non-instrumental navigation. In the second part, I address the question of whether make-perceive may help to account for the "phenomenal presence" of occluded or otherwise hidden features of perceived objects. I argue that phenomenal presence is not well explained by the hypothesis that hidden features are represented using projected mental images. In defending this position, I point to important phenomenological and functional differences between the way hidden object features are represented respectively in mental imagery and amodal completion.

By absence this good means I gain, / That I can catch her,
Where none can watch her, / In some close corner of my brain…
–From "Present in Absence," attributed to John Donne.

1. Introduction: Augmenting Reality with Mental Imagery

The currently most developed and influential theory of visual mental imagery is that of Stephen Kosslyn (Kosslyn 1994, Kosslyn 2005, Kosslyn *et al*. 2006). Kosslyn's theory is based on a model of visual object recognition. According to the model, objects are identified when inputs from topographically organized areas in the occipital lobe, collectively referred to as the "visual buffer," are successfully matched against representations stored in long-term memory. When bottom-up inputs from the visual buffer do not clearly specify the presence of a particular object (or kind of object), representations of the features of the best matching object are accessed by an information shunting subsystem. This subsystem performs two strategic, top-down functions. First, it relays information to other subsystems, enabling them to allocate attention to the presumed location of a diagnostic part or feature of the best matching object. Second, it primes the representation of that part or feature in an object-properties processing subsystem to facilitate its encoding. Conscious

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mental imagery is generated when a stored representation is primed so strongly in the latter system that its activation is propagated backwards along recurrent pathways, inducing a representation of the relevant part or feature in the visual buffer.

Mental images generated during perception, Kosslyn argues, can be used to augment degraded or incomplete perceptual inputs, e.g., to enhance representations of a tree partly enveloped in mist or a man hidden in shadow (Kosslyn & Sussman 1995, Lewis *et al.* 2011). Imagery can be projected or "superimposed" on locations in a perceived scene for a variety of other purposes, however. When moving into a new home, for example, one might look at the front door, while simultaneously imagining how a sofa would need to be turned in order to fit through it. Or, when planning the interior decoration, one might inspect an unfurnished room, while visualizing a bookcase in an empty corner or a carpet on the floor. Last, when deciding on how to the paint the bedroom walls, one might imaginatively stain them with different colors. Yet another familiar example of imaginatively augmented perception is the experience of noticing a constellation in the night-time sky. Noticing a constellation is a hybrid, visual-imaginative experience: it involves both seeing the stars in the constellation and imagining the lines that connect them at the same time. In what follows, I shall refer to such hybrid experiences − involving both a bottom-up, perceptual component and a top-down, imaginative component − as "make-perceive" (Briscoe 2008, 2011).

In many cases, make-perceive is deliberate and agent initiated: mental images are actively projected and altered in response to incoming visual information and changing task demands. Other cases of make-perceive, however, are passive in that they neither involve effortful visualization nor are susceptible to top-down control. Examples include hallucinations and perhaps certain cases of color-grapheme synaesthesia (Barnett & Newell 2008). Passive make-perceive may also help to explain illusions in which one's experience of a gray-scale picture of an object (Delk & Fillenbaum 1965, Hansen *et al*. 2006, Witzel *et al*. 2011) is influenced by stored information about the object's characteristic color (this is sometimes referred to as the "memory-color effect"). In experiments by Hansen and colleagues, subjects were instructed to adjust to a color photograph of a banana until it appeared completely achromatic. The picture was generally perceived to be colorless, however, only when its color was shifted away from neutral grey toward a slightly bluish hue, i.e., in a direction opposite to a banana's typical color. This suggests that when the picture was photometrically achromatic, subjects still perceived it as having a slightly yellow appearance. One empirically plausible explanation of this effect is that viewing the achromatic picture elicits a mental image of a yellow banana, which is then amalgamated with bottom-up perceptual signals (Macpherson 2012). Last, Gosselin and Schyns (2003) have shown that subjects will sometimes report seeing a smiling face in a white-noise display when they are led to believe that it is present there. "As white noise does not represent coherent structures in the image plane," they write, "the superstitious perception of a signal had to arise from the observers' share" (2003, 505). Such "superstitious perception," as Gosselin and Schyns call it, seems well explained by the hypothesis that subjects' expectations caused them to superimpose, unknowingly, a mental image on the screen in front of them.

Importantly, when the observer's share in make-perceive is deliberate or active, the imaginative and perceptual components of the agent's hybrid experience are introspectively distinguishable: the imaginative component, unlike the perceptual component, is subject to top-down control and, so, can be altered or extinguished at will. When make-perceive is passive, however, the imaginative and perceptual components of the agent's experience may be difficult or impossible to tell apart through introspection. One may seem to be in one (purely perceptual) state rather than two (perceptual and imaginative). Well-known experiments by Perky (1910) show that agents, under certain conditions, mistake what they are seeing for what they are imagining. But cases of passive make-perceive show that it is also possible for agents to mistake what they are imagining for what they are seeing.[1]

The examples discussed for far have all involved *visual* perceptual-imaginative hybrids. Make-perceive, however, can cross modal lines: visual perceptual experiences can combine with imagery in non-visual modalities. Seeing a picture of a rose or of a piece of Roquefort cheese, for instance, may elicit olfactory imagery. Seeing a prickly cactus or a cashmere sweater may elicit tactile or kinaesthetic images of what it would feel like to brush against its surface with one's hand.[2] Seeing a speaker's lips moving in the absence of audible speech sounds may elicit auditory images of the words she is articulating (Calvert *et al.* 1997; for discussion, see Spence & Deroy 2013).

The perceptual or bottom-up element in make-perceive, it should also be emphasized, need not be visual. When one explores or feels around for an object in a completely dark room at night, one's tactile experiences may be supplemented with projected visual images of the room's layout or the shapes of the various pieces of furniture it contains. In this case, the perceptual contribution is tactile, while the top-down, imaginative contribution comes from vision. (For discussion of touch-driven visual mental imagery, see Sathian *et al.* 2001, Zhang *et al.* 2004, and Lacey & Sathian 2013.) In congenitally blind subjects who make use of echolocation or auditory-tactile sensory substitution devices, bottom-up auditory information about the way objects and surfaces are arrayed in space may be augmented with tactile imagery generated by the "mind's hand" (Renzi *et al.* 2013). Many different crossmodal perceptual-imaginative permutations clearly seem to be possible.[3]

My discussion in the rest of this paper has two parts. In the first part, I show that make-perceive can enable agents to perform certain actions and engage in certain kinds of problem-solving more effectively than bottom-up perceiving or top-down imagining alone. In the second part, I turn to the question of whether make-perceive may help to account for the "phenomenal presence" of occluded or otherwise hidden features of perceived objects (Sellars 1978/2007, Nanay 2009). I argue that phenomenal presence is not well explained by the hypothesis that hidden features are represented using projected mental images. In defending this position, I point to some important phenomenological and functional differences between the way occluded features are represented respectively in mental imagery and amodal completion.

2. Make-Perceive and Problem Solving

The process of superimposing mental imagery on a visually perceived scene is an example of what Gilles Fauconnier refers to as cognitive "blending." Fauconnier writes: a "blend operates in two input mental spaces to yield a third space, the blend. Partial structure from the input spaces is

[1] Hence they involve what Brian O'Shaughnessy (2000) calls a "disturbance of one's sense of reality (352); they are mistakenly taken to be a "true seeing of a real presence" (354). By contrast, the kind of presence that attaches to the imaginatively represented object in cases of active make-perceive, O'Shaughnessy says, is "'thin' and unconvincing" (349), i.e., not liable to being mistaken for real presence.

[2] The tendency visual experiences have to evoke tactile and kinaesthetic imagery is, in fact, the basis of the Berkeleyan theory of visual space perception. "[I]n strict truth," Berkeley writes, "the ideas of sight, when we apprehend by them distance and things placed at a distance, do not suggest or mark out to us things actually existing at a distance, but only admonish us what ideas of touch will be imprinted in our minds at such and such distances of time, and in consequence of such or such actions (1734, §44). Importantly, the tangible ideas to which Berkeley here refers are not perceptions of overt movement and touch, but rather "only objects of the imagination" suggested to the observer by sight (1733/1975, §§9-10).

[3] For broad discussion of crossmodal mental imagery in which "in which the presentation of a stimulus in one sensory modality results in the formation of a mental image in another modality," see Spence and Deroy 2013.

projected into the blended space, which has emergent structure of its own" (1997, 150). In cases of what I am here calling make-perceive, the inputs respectively come from perception and imagination, and the emergent blend is a visual-imaginative composite or hybrid experience. Edwin Hutchins (2005) refers to this particular kind of composite as a "materially anchored blend" since one source of input to the mix is an external, visually perceived scene in the world.

Perceptual and imagination-based reasoning are powerful modes of nonconceptual cognition indigenous to the biological brain. The examples surveyed below in this section serve briefly to illustrate how their blended use enables human agents to solve certain types of problems and to carry out certain projects more effectively than bottom-up perceiving or top-down imagining alone.[4]

Action Guidance:

Before deciding what to do or how to move in relation to a perceived scene, human beings can form covert, tactile-kinaesthetic "motor images" (Jeannerod 2006) of different possible actions. For example, before attempting to transport a heavy and unwieldy object, we might imagine different ways of lifting it so as to determine which set of grasp points would minimize torque forces. Or, when engaged in rock climbing, we might imagine different ways of positioning our hands and feet on the surfaces in front of us so as to determine the next set of advantageous holds. In both cases, we not only overlay motor images of possible actions on the visually perceived environment, the specific motor images we form are guided by incoming perceptual information about the spatial and material properties of objects around us. In this respect, among others, imagining the performance of an action in relation to a perceived object is analogous to actually performing the action in question (for a review of empirical findings, see Jeannerod 2006, chap. 2). The ability to engage in such sensorimotor make-perceive – and to thereby anticipate the tactile and kinaesthetic consequences of spatially directed bodily movement – is clearly adaptive: it permits us to simulate and evaluate possible actions "offline" before risking them overtly in the harsh world (Berkeley 1709/2008, Dennett 1995, Grush 2004, Vaughan & Zuluaga 2006).

We can covertly imagine moving in relation to the perceived environment. But overt behavior can also be guided by items and features that we make-perceive in nearby space. Actions performed in processes of artistic and technological creation, for example, frequently depend on the ability imaginatively to add or subtract structure from visually perceived objects. The sculptor (or early tool maker) looks at a piece of stone, visualizes how it would appear if *this* bit were knapped or chiseled away, performs the proper sculpting action, and then evaluates the outcome. This sequence is then re-iterated with imaginative modifications to currently existing visual structure determining the goal of action at each step. A similar pattern no doubt characterizes aspects of the design process in drawing (but for limitations on the role of imagery here, see Van Leeuwen, Verstijnen, & Hekkert 1999).

Other relevant cases involve the production and interpretation of various kinds of pretend behavior (Van Leeuwen 2011). A child may swing a sword that she visualizes in her empty hand while another child ducks to avoid it. Or a mime may reach for a glass of wine that she and those watching her performance imaginatively project on a nearby table. In cases like these, the motor commands the agent forms are guided by the spatial, material, and functional properties of the

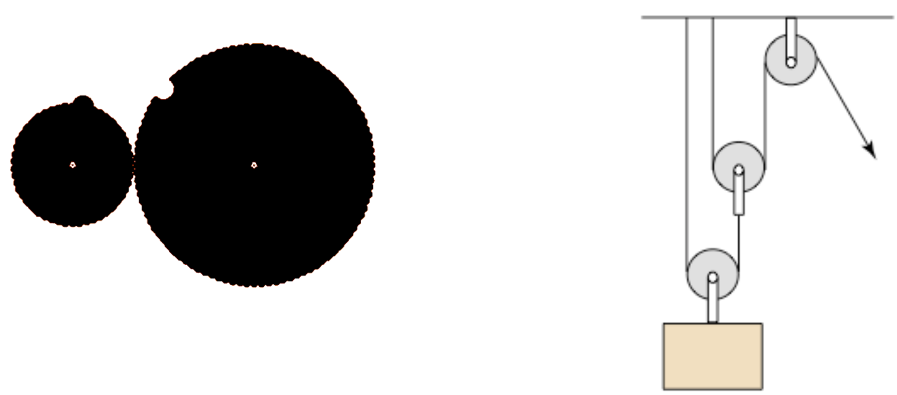
[4] There are good reasons to think that abilities to "comment" on visually perceived scenes with auditory imagery, in particular, with internally recited utterances, play an important role in early childhood word learning and various forms of skill-acquisition (Vygotsky 1962/1986, Dennett 1993, Diaz & Berk 1992, Gauker 2011). Since the cognitive dividends of this kind of visual-auditory make-perceive have been extensively examined elsewhere (see especially Clark 1998), I shall not discuss it here.

objects with which she imaginatively populates space around her.

Diagrammatic Reasoning:

Numerous studies implicate make-perceive in the interpretation of static machine diagrams. Schwartz & Black 1996, e.g., presented subjects with a computer display of two touching gears (**Figure 1a**). Their task was to determine as quickly and accurately as possible whether a knob on one gear and a groove on the other would mesh when the gears were rotated inward. If subjects imagined the rotation of the gears in order to solve this problem, then, it was predicted that their response times would be longer when the knob and groove were placed further apart from the meshing point. And this was just what the experimenters found.

Other findings support the idea that "mental animation," as Mary Hegarty calls it, can be used to infer the kinematics of a mechanical system from a static visual display. **Figure 1b** depicts two pulleys. When the free end of the rope is pulled, will the lowermost pulley turn clockwise or counter-clockwise? Studies by Hegarty and colleagues (Hegarty 1992, Hegarty *et al*. 2003, Hegarty 2004) have found that when subjects solve problems like this one, they mentally animate the motions of the system's components in a sequence that corresponds to the causal order of visual events in the system's operation.[5] Eye-tracking data are consistent with this account. When asked to predict the motion of a particular component, e.g., the middle pulley in **Figure 1b**, subjects look at that component as well as components earlier in the mechanical process, e.g., the uppermost rope and pulley, but not at components later in the process. The input spaces to the cognitive blend here include the machine diagram and superimposed movement imagery. "Running the blend" by means of mental animation enables agents to substitute fast, analog simulations of simple physical interactions for slower, propositionally articulated forms of inference-making.[6]



a b

Figure 1
(a) Gears problem. Source: Schwartz & Black 1996.
(b) Pulley problem. Source: Hegarty 2004.

[5] Hegarty & Steinhoff 1997 and Hegarty & Kozhevnikov 1999 find that mental animation ability is highly related to spatial ability, but not verbal ability. Correspondingly, Sims & Hegarty 1997 find that mental animation interferes more with visuospatial working memory than with verbal working memory.

[6] It should be emphasized that Schwartz and Hegarty's findings are likely have numerous corollaries in real-world, causal reasoning. As Christopher Gauker (2011) emphasizes, many practical problems can be solved using nonconceptual, imaginative representations of how things go together and causally interact. When assembling a piece of furniture from IKEA for example, we may play a game of mental Tetris®, trying out possible imaginative fits between the parts spread out on the floor.

Navigation:

My final example derives from Edwin Hutchins's well-known studies of long-distance, non-instrumental navigation among the Caroline islanders of Micronesia (Hutchins 1984, 1995, 2005). The Caroline islanders, like other traditional seafaring communities, have learned to use the night-time sky as a compass while at sea. At any given latitude, a star always rises at the same azimuth on the eastern horizon and always sets at same azimuth on the western horizon. A linear constellation or "star path" is a set of stars that describe the same stationary arc from east to west. **Figure 2** illustrates the rising positions of 10 of the fourteen linear constellations familiar to Micronesian navigators, with east being the direction of the path for the star Altair. When the bearings of the rising and setting positions are combined, the result is a stable compass in the night-time sky. Importantly, a skilled navigator can construct the entire compass in imagination from sightings of only one or two stars near the horizon.

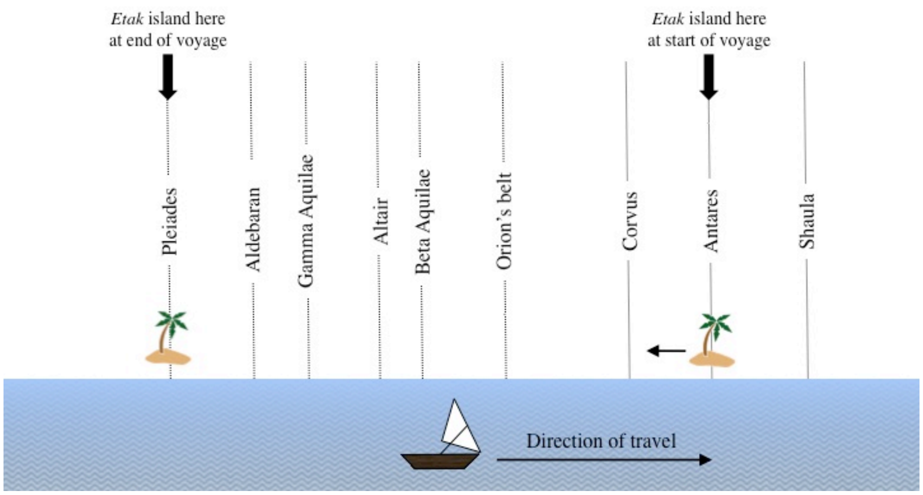


Figure 2
Navigating with reference to the star bearing of an *etak* island. After Hutchins 1995, 86.

The Micronesian sidereal compass performs two main functions at sea. First, it enables the skilful pilot to maintain accurate bearings of distant islands that are well out of sight. From any given point of origin, the pilot knows the star bearing in the direction of which he must travel to reach any other island within sailing range. Second, it enables the navigator to keep track how much of a trip has completed while traveling on a sealane between two islands (**Figure 2**). In order to perform this function, however, it must be combined with an impressive application of make-perceive. For every voyage from one island to another, the pilot imagines a third island to the side of the course and over the horizon, called the *etak* island (Hutchins 2005, 1567-69). Unlike Western, technologically equipped navigators, Micronesian navigators do not conceive of the voyage using a geocentric spatial framework, that is, in terms of the movement of canoe between two fixed locations on the Earth's surface, but rather *egocentrically*, in terms of the changing star bearing of the *etak* island relative to the canoe. Hutchins writes:

> …at the beginning of the voyage, the *etak* island will be at the star bearing of the *etak*

> island from the origin. At the end of the voyage, when the canoe has reached the destination, the etak island will be at the bearing of the etak island from the destination. Thus, during the voyage, the etak island appears in the navigator's imagination to move back along the horizon…. The *etak* island is under one star at the beginning of the voyage and under another at the end of the voyage. By superimposing the imagined movement of the etak island on the frame of the star bearings, the Micronesian navigator creates a model of the voyage that he can see and manipulate from his point of view on the deck of the canoe (2005, 1567-68).

Although space does not permit detailed discussion, it is clear that the *etak* navigation system permits the skilled Micronesia pilot to discern spatial relations and to make inferences in ways that would otherwise be difficult or impossible without the use of maps, tables, global positioning satellites, or any of the other external technologies standardly employed by modern seafarers. This example again illustrates the point that strategically combining perception and imagination can yield representational dividends that far surpass their respective, independent contributions to cognition and action planning.

3. Make-Perceive and the Problem of Phenomenal Presence

In the previous section, I surveyed only a few of the ways in which projected or "materially anchored" mental imagery can facilitate problem solving. I now turn to the question of whether make-perceive may play a much more pervasive and basic role in our everyday visual experience of objects in space around us.

Visual perception is inherently perspectival. One consequence is that from, any given position in relation to an opaque, solid object, we only see part of the object's surface. The side of the object that faces us hides its back-side from sight. Another consequence is that objects that are closer in depth often partially occlude those that are further away. Despite these limitations, when observers[7] see an object, they usually have a sense of its presence as a complete, three-dimensional whole. As Nakayama and colleagues write: "Often we see multiple surfaces in local regions of visual space, with closer objects at least partially covering those behind…. Yet remarkably, we do not feel much loss of information when part of a surface is rendered invisible by occlusion; we do not see invisible surface regions as nonexistent" (1995, 2). When we see a cat standing behind a picket fence, for example, we see what appears to be a single, intact animal partially hidden by a series of vertical slats. The parts of the cat that are visible to us are not experienced as spatially disconnected, but as continuing behind the pickets and as belonging to the same object.

What, however, does it mean to say that "we do not see invisible surface regions as nonexistent"? How can it be the case that what is hidden from sight is nonetheless experienced as present in the perceived scene? In what follows, I shall refer this as the problem of "phenomenal presence."

In a recent discussion, Bence Nanay treats the problem of phenomenal presence as distinct from the problem of explaining how we represent the hidden features of the objects we perceive (Nanay 2009). Whereas the former is construed as a phenomenological problem – "[H]ow," Nanay asks, "can we explain that what it is like to be aware of the occluded parts of perceived objects is similar to what it is like to perceive those parts that are not occluded?" (2009, 252) – the latter is construed as a problem about representational format. Are the representations that complete (or,

[7] Including young human infants and, perhaps, some non-human animals. For a review of the literature on amodal completion in human infants, see Bower 1982, Condry *et al.* 2001, and Otsuka *et al.* 2006; in monkeys, apes, rodents, and birds, see Mascalzoni & Regolin 2010.

as vision scientists say, "interpolate") the hidden parts of the cat's body properly perceptual in nature? Or are they rather non-perceptual beliefs that we infer partly on the basis of what we see and partly on the basis of background knowledge?

There is a Kantian-Sellarsian view of the role of imagination in perception that provides yet a third possibility. According to Sellars, the capacity that Kant (1787/1997) calls productive imagination constructs hybrid "sense-image models" of the objects that we perceive. It performs this function, in part, by supplementing awareness of an object's "occurent sensible features" with mental images of its hidden features. Sellars writes: "We do not see *of* the apple its opposite side, or its inside, or its internal whiteness… But while these features are not *seen*, they are not *merely* believed in. These features are present in the object of perception as actualities. They are present by virtue of being imagined" (1978/2007, 458).

Nanay adopts this Kantian-Sellarsian view. Like Sellars, he argues that we represent the hidden features of the objects that we perceive by means of projected mental imagery (Nanay 2009, 250). Further, he argues that this view provides, as a corollary, an account of phenomenal presence:

> …if what it is like to have visual imagery is similar to what it is like to perceive and being aware of occluded parts of perceived objects is having visual imagery, then, putting these two claims together, we get that what it is like to be aware of the occluded parts of perceived objects is similar to what it is like to perceive those parts that are not occluded. Thus, my proposal that we represent the occluded parts of perceived objects by means of mental imagery has the additional advantage that it gives a simple answer to the question of perceptual presence (2009, 252).

I agree with Sellars and Nanay that we sometimes represent the hidden features of perceived objects by means of projected mental imagery, that is, by means of the capacity that I am calling "make-perceive." There are reasons to think, however, that this is far from the whole story. In what follows, I argue, first, that we should distinguish traditional cases of "amodal completion" (Michotte *et al.* 1964/1991, Kanizsa & Gerbino 1982), in which relatively low-level visual processing mechanisms complete hidden object features on the basis of incoming sensory input, from cases in which the agent generates mental images of hidden object features on the basis of information stored in long-term memory. Second, I argue, contrary to Sellars and Nanay, that the problem of phenomenal presence is not adequately solved by what I call the "image-based completion" account. The representations that causally support our sense that certain features of perceived objects are really present, though hidden from sight, are properly perceptual representations formed by the mechanisms of amodal completion.

3. Amodal Completion

A standard way of drawing distinction between "modal" and "amodal" completion by students of perception is as follows. In modal completion, the observer characteristically has a distinct, quasi-visual impression of a contour or surface where there are no corresponding stimulus features in the retinal image. Natural scenes that most commonly give rise to modal completion are those in which a foreground surface is camouflaged by a more distant background surface. As a familiar example of this type of completion, consider the illusory Kanizsa squares in **Figure 3.** Most observers report having the impression of seeing a "thin" square on the left, in which the illusory, vertical contours bow inwards, and the impression of seeing a "fat" square on the right, in which the illusory, vertical contours bow outwards. The interpolated illusory squares exemplify the "phenomenal filling-in" characteristic of modal completion (Pessoa *et al.* 1998).

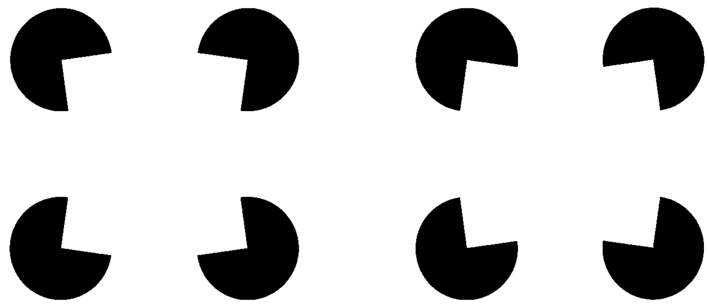


Figure 3
Illusory Kanizsa Squares

By contrast, "amodal" completion occurs when one object is (or appears to be) partially occluded by another and does not typically result in a quasi-visual impression of the object's hidden features. Amodal completion is not characterized by phenomenal filling-in – hence, the epithet "amodal." Rather, the phenomenally most salient characteristic of amodal completion is the perceived *unity* of the partially occluded object (Michotte 1964/1991, Kanizsa 1979). When see a cat walking behind a picket fence, we do not see a moving array of spatially disconnected cat parts. Rather see what appears to be a single, intact cat that is partially visible and partial out of sight.

As another illustrative example of amodal completion, consider **Figure 4a**. Notice here that although it would reasonable to infer that the occluded object is an octagon given the surrounding context, the completion that the visual system "prefers" is shown in **Figure 4b**. This example nicely illustrates the point that the interpolation process in amodal completion follows "follows complex principles of its own" (Pylyshyn, 1999, 345) and is not rationally sensitive to the observer's beliefs and other high-level cognitive states.

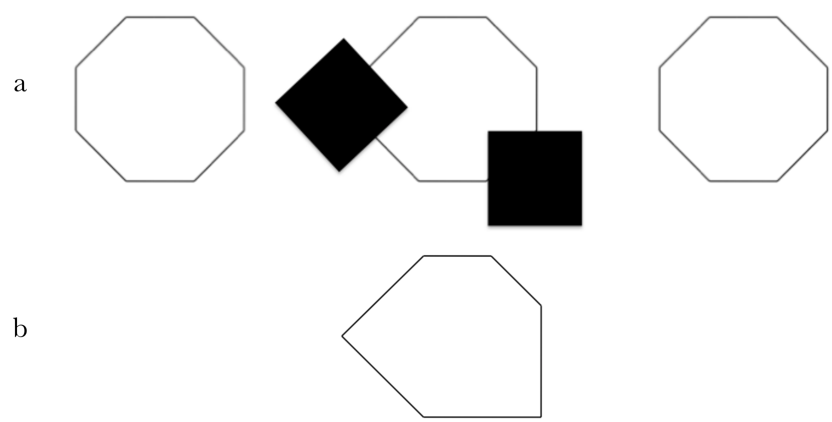


Figure 4
Amodal completion follows its own organizational principles.

Such "non-cognitive" characterization of amodal completion, is supported by empirical evidence that amodally completed contours are represented by stimulus-driven cell-activations in early visual processing areas such as V1 (primary visual cortex) and V2 (Sugita 1999, Bakin *et al.* 2000, Kamitani & Shimojo 2004, von der Heydt 2004, Komatsu 2006).[8] Sugita 1999, e.g., found that amodal completion in V1 is modulated by binocular disparity. Orientation-selective cells in V1 were presented with two vertical line segments separated by a gray patch. When the patch was presented with zero disparity or uncrossed disparity, so that it appeared, respectively, on the same or a more distant plane of depth than the line segments, the cells did not respond. However, when the patch was presented with crossed disparity, so that it appeared to be in front of the line segments (a stimulus consistent with occlusion of a single, vertical bar), the cells responded vigorously. Psychophysical evidence that occluded objects are completed rapidly at early levels of human visual processing is provided by Rensink & Enns 1998 and Johnson & Olshausen 2005. The latter team of investigators found that ERP (event-related potential) differences between images of occluded objects, e.g., a violin partly hidden by a disc, and images in which object regions are deleted rather than occluded, e.g., a violin with a disc-shaped cutout, occur as early as 130 ms after presentation.

Before proceeding, two further points are in order. First, important work by Peter Tse (1999) suggests that amodal completion operates at the level of volumes or 3-D enclosures. Tse presents a large number of demonstrations that cannot be explained by familiar contour-relatability (Kellman & Shipley 1991) or surface-completion theories (Nakayama & Shimojo 1992, Nakayama *et al.* 1995), but that are adequately accounted for by his volume-based account. According to Tse, the inputs to the completion process are local surfaces plus the voluminous "insides" specified by them and the outputs are maximally closed surfaces in which the local insides are merged. One important implication of this account is that amodal completion is not limited to cases in which an object is partially hidden by an object closer in depth, but will also occur in cases of self-occlusion. "Amodal completion," Tse writes, "does not only happen behind an occluder. It is a universal aspect of volume completion, since all objects self-occlude their far side and therefore occlude their true extent. The real problem… is not amodal completion at all, but 3-D shape formation or volume completion. What has traditionally been called 'amodal completion' is just a small subset of all volume completion phenomena" (Tse 1999, 62-63). On this approach, the kind of surface-based completion familiar from demonstrations consisting of flat, overlapping shapes (as in **Figures 3, 4, 5, and 6**) is treated as a special case in which completion takes place among "'degenerate' volumes that do not have insides" (Tse 1999, 42). In **Section 4** below, I suggest that our sense of the phenomenal presence of an object's self-occluded parts is plausibly explained by the perceptual mechanisms involved in such amodal volume completion.

[8] It should be emphasized, however, that the mechanisms of amodal completion extend far into higher-levels in the visual processing hierarchy. Hegdé *et al.* 2008, using fMRI, found foci in the lateral occipital complex (area LOC) and the dorsal intraparietal region that are preferentially responsive to occluded objects, i.e., their response to the presentation of an occluded object is significantly larger than their response to either the object or the occluder by itself.

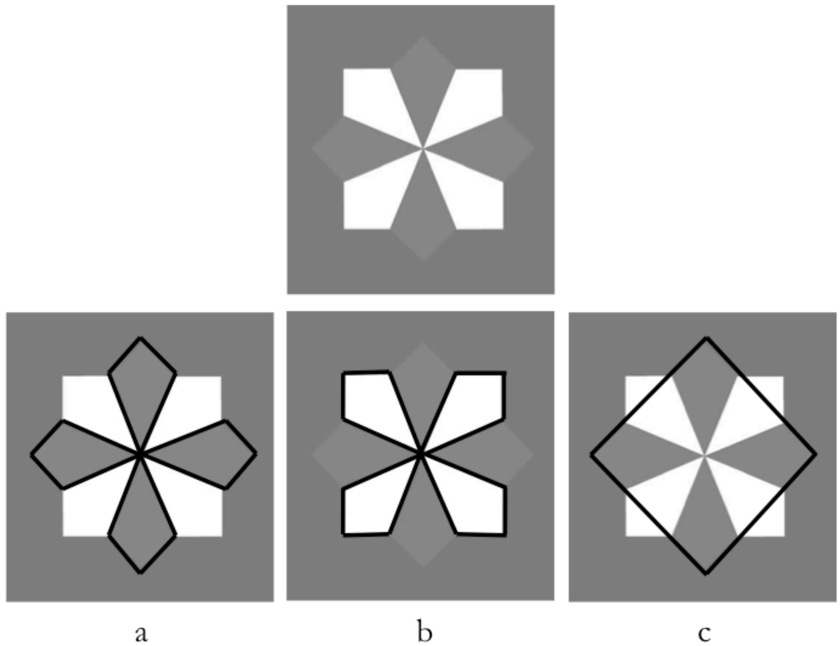


Figure 5
Edgar Rubin's Maltese Cross. Adapted from Shapely *et al.* 2004.

Second, although representations of occluded object-features formed in early visual processing areas do not result in the "filling-in" characteristic of modal completion, they nonetheless make an important contribution both to the phenomenology and content of conscious visual experience. In particular, they play a significant role in the *spatial organization* of the 3-D scene that we perceive. This point can be brought out by reflection on Edgar Rubin's "Maltese Cross" reproduced in **Figure 5**. The perception evoked by the Maltese Cross is ambiguous or multi-stable, meaning that, with prolonged viewing, figure/ground assignments can alternate. On assignment (a), we see an upright, dark grey cross on a partially occluded a white square (completed amodally in the background). On assignment (b), by contrast, we see a white cross, tilted on its side, partially occluding a dark grey diamond. On a yet a third assignment, (c), we perceive a grey and white diamond, partially occluding a white square. Notice that it is not only the relative depth relations that flip between these three assignments: there also changes at the level of the *objects* that we perceive. E.g., in assignment (b) we see a white cross and a grey diamond, objects that are absent in assignment (c).

This example nicely illustrates the point that amodally completed contours, surfaces, and volumes are not extra-perceptual *addenda* to what we "strictly speaking" see. Rather, amodal completion plays an integral role in perceptually segmenting the visual scene into discrete, 3-D objects at different distances in depth (Nakayama *et al*. 1995, von der Heydt 2004, Fleming & Anderson 2004). Indeed, without the stimulus-driven processes that result in amodal completion (and modal completion), the question of how we represent the occluded features of discrete, 3-D objects would not arise because we would not *see* coherently organized scenes consisting of such objects.[9]

[9] For related discussion, see Briscoe 2008 and Briscoe 2011.

4. Image-Based Completion and the Problem of Phenomenal Presence

Not all completion of hidden structure is of a perceptual, non-cognitive character. Rather, completion can also take place at the level of projected mental imagery or "make-perceive."[10] E.g., when we see the tip of a pink snout protruding from behind a barn door, we may be disposed to imagine a pig hidden on the other side. Unlike amodal completion, such "image-based completion" is highly dependent on background knowledge. In particular, it involves *identification* of the partially occluded object and, hence, accessing categorical information stored in long-term memory. Unlike amodal completion, image-based completion processes are thus cognitively penetrable – they can be "altered in a way that bears some logical relation to what the person knows" (Pylyshyn 1999, 343). How we imagine the occluded pig attached to the snout, e.g., depends on our conceptions about a pig's normal visual appearance.

The image-based completion account comprises two claims: First, as Nanay writes, "[w]hen we represent the occluded parts of perceived objects, we use mental imagery… in a way that would allow us to localize the imagined object in our egocentric space" (2009, 250), i.e., we engage in make-perceive. Second, the occluded parts of a perceived object are phenomenally present in our experience of the object *because* they are represented using mental imagery.

The basic problem with the first claim is straightforward: it fails to distinguish between non-cognitive, amodal completion and cognitive, image-based completion. Some completion of hidden structure is properly perceptual in nature and does not involve any top-down mental imagery.[11]

Significant phenomenological and functional differences between the two forms of completion, however, also challenge the second claim. First, interpolated contours, surfaces, and volumes in amodal completion do not have a visual or quasi-visual phenomenology. What it is like to be aware of the occluded parts of a cat standing behind a picket fence is *not* similar to what it is like to be aware of the parts of the cat that are in sight. The occluded parts are phenomenally present – as evidenced in the perceived unity of the cat to which they belong – but they are, as Kanizsa & Gerbino 1982 put it, "amodally present." Conscious mental imagery, by contrast, has a modally visual phenomenological character: objects represented in mental imagery are experienced as having as visible shapes, sizes, and colors. This suggests that mental imagery is not operative in at least some paradigmatic cases of phenomenal presence.

Second, mental images are not *stable* in the absence of sustained effort and fade rapidly. As Hume puts it, "in the imagination the perception is faint and languid, and cannot without difficulty be preserv'd by the mind steady and uniform for any considerable time" (1739/2000, 11). By contrast, amodal completion phenomena normally stably persist so long as one perceives their inducers. No more effort is required to see the partially occluded discs in **Figure 3** than to see the squares that occlude them. In short, image-based completion, unlike amodal completion, is

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[10] I here focus on visual perceptual completion. See Spence & Deroy 2013 for discussion of some possible roles for non-visual imagery in crossmodal perceptual completion.

[11] Neuropsychological studies of associative visual agnosia indicate that brain lesions can selectively impair abilities to recognize objects on the basis of their visual appearance, while leaving perceptual organization intact (Farah 2001). A subject with associative visual agnosia, e.g., presumably would experience a cat partially hidden behind a picket fence as a single, unified object even in the absence of the ability to recognize it as a cat or even an animal. The relevant implication, in the present context, is that high-level processing functionally necessary for mental image formation (at least on a model like Kosslyn's) is not necessary for representing the occluded parts of perceived objects. For empirically informed discussion of the relationship between amodal completion and visual object recognition, see Nakayama *et al.* 1995.

introspectively dependent on the agent's own activity. In consequence, its products are not likely to be experienced as having real presence in the perceived scene.

Third, mental images are not *obligatory*. When we see a pink snout protruding from behind a barn door, we may imagine the shape of a hidden pig, but we may also imagine any of variety of other things instead, or indeed nothing at all. By contrast, our experience of amodal completion is not similarly subject to volition or top-down influence. Amodal completion, far from exhibiting what Hume called the "liberty of the imagination" (1739/2000, 12), operates automatically in accordance with a fairly strict set of organizational principles and is largely driven by bottom-up sensory inputs. Our experience of seeing visible surfaces and volumes as belonging to a single, unified object in amodal completion, in consequence, thus is not pliant in the way that we would expect it to be were they represented using mental imagery. It is precisely the absence of pliancy or top-down control that is characteristic of phenomenal presence, however.

Last, on the Sellars-Nanay account, make-perceive is supposed to explain how we represent hidden features both in cases of *superposition*, in which an object's visible surfaces hide parts of the more distant background, and *self-occlusion*, in which an object's near side hides its far side. In cases of superposition, both the object's visible surfaces and hidden background regions are represented from a single, unified visual perspective. Visual perception and visual imagination share a common, egocentric point of view. In cases of self-occlusion, however, the perspective of perception and the perspective of imagination come apart. The spatial point of view from which I see the visible surfaces of a car (and egocentrically locate them relative to myself) and the point of view from which I imagine the car's self-occluded surfaces, i.e., the surfaces that I would see were I counterfactually to view the car from a position facing its far side, are *different* points of view. Hence, it seems unlikely that the Sellars-Nanay account of superposition can be unproblematically extended to cases of self-occlusion.

By contrast, stimulus-driven amodal completion does not only occur in cases of superposition. Studies conducted by Peter Tse, mentioned above in **Section 3**, suggest that the mechanisms of amodal completion typically interpolate self-occluded, volumetric structure.[12] Hence there is reason to suppose that the phenomenal presence of such structure may be causally explained by the construction of representations that are properly perceptual, i.e., non-imaginative, in nature.

5. The Functional Effects of Amodal Completion

At this point in the argument, the following reply might be made on behalf of the image-based account. It is plausible that *active* make-perceive does not account for the phenomenal presence of hidden object features. The products of deliberate imagining or visualization, unlike those of perception, are subject to top-down control and, in consequence, are not experienced as objectively "out there" in the world. The products of *passive* make-perceive, however, are not so easily distinguished from those of perception. In some cases, they are stable and cannot be altered at will by the agent, e.g., the spots of blood that Lady Macbeth hallucinates on her hands. The same would go for the memory-color effect, if, as Macpherson (2012) argues, the underlying mechanism involves "unbidden" mental imagery. The yellowish appearance of the grey banana picture in the experiments performed by Hansen and colleagues (2006), unlike a product of active, agent-initiated imagining, is stable, automatic, and inducer-specific.

[12] Although as Tse emphasizes, volume completion processes do not always interpolate the exact form of hidden regions. "To the extent that an occluded form is interpolated in may be probabilistic in nature" (1999, 50).

A proponent of image-based completion might thus argue that, when we represent hidden object features, we do so by means of mental images that are passively formed and that are insusceptible to top-down control. The features of objects represented in such imagery would plausibly have phenomenal presence even if those represented in actively projected mental images do not. As Brian O'Shaughnessy writes: "to the extent that a visual imagining is insightfully experienced as *imagining*, to that extent it is experienced as a mere *quasi-seeing* of an '*unreal presence'*, while to the extent that it is *not* so insightfully experienced as imagining, to that same extent it is experienced a true seeing of a real presence" (2000, 354).

While this proposal is not *prima facie* implausible, it faces a number of objections. First, as emphasized above, conscious visual mental images have a modally visual phenomenology. The passive projection of such images thus cannot explain the phenomenal presence of object features that are *not* experienced in a modally visual way. What explains the modal phenomenal presence of Duncan's blood on Lady Macbeth's hands cannot explain the *amodal* phenomenal presence of the hidden parts of the discs in **Figure 3.**

Second, the passive make-perceive account also fails to address the self-occlusion objection voiced in the last section. A solution to the problem of phenomenal presence, however, should plausibly explain both cases of superposition and cases of self-occlusion.

The most serious objection, however, is perhaps the third. As argued above, amodal completion performs a fundamental role in perceptual organization, i.e., in grouping and segmenting visible contours, surfaces, and volumes in depth. The amodally-completed regions of an object or scene often contribute as much to its perceived spatial organization as do its visible, non-occluded regions. And it is this, no doubt, that confers on the products of amodal completion their distinctive phenomenal presence: they have genuinely perceptual functional effects.

Projected mental images are not suited to play such an organizational functional role. The main reason is that mental image formation, whether active or passive, is guided by information stored in long-term visual memory. Perceptual organization, however, is highly insensitive to such top-down influence. When we view **Figure 6**, for instance, we see what appears to be a horse with an extremely long mid-section standing behind by a vertical, grey occluder. This perceived organization, however, is at variance with our stored information about horses and their visual appearance. It is not the organization that would be predicted by the image-based completion account.

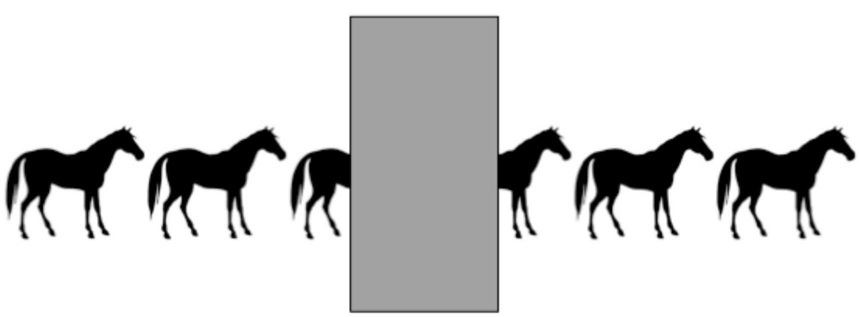

Figure 6
Perceptual organization is sometimes at variance with background knowledge.

6. Conclusion

Imagination, according to Kant, is the faculty by means of which what is perceptually absent is made present (1997, B151). It is thus natural to suppose, as do both Sellars and Nanay, that imagination is the faculty by means of which we represent the occluded or otherwise hidden features of perceived objects. I have argued here that this natural supposition is false. The representations that give rise to the sense of the phenomenal presence are properly visual representations formed on the basis of incoming sensory input, rather than information stored in long-term memory. These representations play a fundamental role in perceptually organizing the scenes we visually experience, a role that mental images are unsuited to play.

As paradoxical as it may sound we thus sometimes perceive the invisible – or rather, we perceive features and parts of objects that do not reflect any light to the eye. This view is much less counterintuitive, however, when placed in the context of relevant psychological work. According to a recently important Bayesian perspective in vision science, for instance, perception is best modeled as a process of probabilistic inference from the retinal image to the distal scene ecologically most likely to have been its causal source (Knill & Richards 1996, Kersten *et al*. 2004, Rescorla forthcoming). From this perspective, in which the early visual system is assumed to have evolutionarily hard-wired or learned "prior knowledge" about natural scene statistics, it makes good sense to suppose that perceptual representations of occluded or obscured contours, surfaces, and volumes will be formed when there is evidence for them in the sensory input (Mamassian 2006, Geisler & Perry 2009). An earlier, compatible view is familiar from work in the Gestalt tradition. "Unlike their sensationist predecessors," Kellman and Shipley write, "the Gestaltists recognized that stimulus variables relevant to perception need not correspond to local sensations. Spatial and temporal relationships in the inputs to the senses might explain how perception can instead be in close correspondence to the outside world" (1991, 141).[13] The absence of proximal sensory stimulation caused by a feature *F*, in other words, does not always entail the absence of stimulus variables that jointly specify the presence of *F*. Last, from a still influential Gibsonian or "ecological" perspective, there are a number of sources of visual information for occlusion in the light sampled by the eye, information that "specifies the existence of one surface behind another, i.e., the continued existence of a hidden surface" (Gibson 1966, 204). These include binocular disparity, T-junctions, and texture deletion under perspective transformation (Gibson 1979, Nakayama *et al*. 1995). For Gibson and contemporary theorists inspired by his work, we sometimes perceive hidden surfaces as directly as we perceive those that hide them.

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[13] For an explicit defense of the view that Gestalt stimulus factors contributing to amodal completion (such as proximity, good continuation, and symmetry) are probabilistic, ecologically valid indicators of "life-relevant physical properties of… remote environmental objects," see Brunswik & Kimiya 1953.

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