A signal-detection-theory representation of normal and hallucinatory perception

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Abstract: Collerton et al.’s perception and attention deficit (PAD) model argues that all recurrent complex visual hallucinations (RCVH) result from maladaptive, deficient sensory and attentional processing. We outline a constructivist-based representation of perception using signal detection theory, in which hallucinations are modeled as false alarms when confirmational perceptual information is lacking. This representation allows for some individuals to have RCVH as a result of a criterion shift associated with attentional proficiency that results in an increased awareness of the environment.

In the target article, Collerton, Perry, and McKeith rely on cognitive psychology models of normal scene perception as a foundation for their proposed perception and attention deficit (PAD) model of recurrent complex visual hallucinations (RCVH). Such cognitive constructivist models propose that scene perception normally uses the sensation or detection of signals available in the environment that are modified by top-down processes, such as memory, expectation, and attentional state (e.g., Rensink 2000a; 2000b). The commonness of illusions (e.g., Post et al. 2003), hallucinations (e.g., Laroi & Van Der Linden 2005) and other forms of misperception of veridical objects confirms the characteristic noisiness of the perceptual construction process. Signal detection theory (SDT) can be used to help disambiguate types of perceptual error that lead to hallucinations (for example, see Ishigaki & Tanno 1999). Specifically, SDT can separate an increase in hallucinations caused by observer inability to discriminate between the presence and absence of objects, from an increase in hallucinations caused by an increased willingness to interpret ambiguous perceptual information. Applying the signal detection theory, we suggest that instances of perception can be classified into four categories: veridical perception (hits), veridical nonperception (correct rejections), lack of awareness (misses), and hallucinations (false alarms).

Collerton et al. provide an impressive array of evidence supporting the PAD explanation, and they rightly point out that many RCVH are associated with systematic neuropathological symptoms. They base much of their thesis on establishing such biological bases, but they singularly argue that all RCVH result from a sensory/attentional deficit. A more global consideration of perceptual error not only examines false alarms, but also considers perceptual errors of omission in which healthy observers are unaware of clearly visible stimuli. A signal-detection-theory characterization allows for a criterion variable, which can bias the ratio of errors of hallucination and errors of omission. This approach entails that some individuals with increased instances of RCVH benefit from an accompanying improvement of veridical percepts because of willingness to err more on the side of false positives versus false negatives. In such individuals, occurrences of RCVH may not be pathological, but rather by-products of a shifted and in some respects enhanced attentional mechanism (Aleman et al. 1999).

Figure 1 shows three signal-detection graphs illustrating a constructionist view of perception in which the presence of an object in the real world can be thought of as a signal to perceive that object. When no object is present, there is a noise-only distribution of how convincing the stimulus is that an object is present. The distribution can be thought of as resulting from factors such as misleading perceptual information, expectation, and varying attentional state. When an object actually exists, the extra sensory/perceptual information or signal is added to create a signal + noise distribution. The noise-only and signal + noise distributions are plotted along an axis indicating the vividness of a percept or, in other words, the convincingness that the experienced stimulus is veridically based on a real object. The criterion line indicates the observer’s threshold for interpreting the stimulus as a real object. Consistent with Collerton et al.’s observation that attention and other top-down cognitive processes mediate perception, we propose that the location of the criterion line depends on an individual’s specific attentional parameters, such as the acuity and range of attention. The criterion line divides each of the two distributions into two regions. The region most strongly emphasized by Collerton et al. is the portion from the noise-only distribution that lies above the criterion line. This region, traditionally thought of as that of false alarms, represents the occurrence of hallucinations, or the perception of objects when none actually exist. Another region that we would like to emphasize is the portion from the signal + noise distribution that lies below the criterion line. This region, traditionally thought of as that of misses, represents the occurrence of lack of awareness of real objects, or insensitivity to signals too weak or unexpected to promote construction of a perceptual object.

Figure 1a illustrates a theoretical set of distributions for a normal observer in which there are both perceptual misses and hallucinations. Here the observer has a criterion line that produces a balance in which there are notably fewer hallucinations than missed perceptions, presumably because of a higher cost for hallucinating. Figure 1b shows a new set of distributions for a pathologic individual as described by Collerton et al. The noise-only and signal + noise distribution are placed closer together to reflect that persons who suffer from pathologic perceptual disorders have difficulty differentiating veridical reality from hallucinated reality. Here, observers have an enlarged region of hallucinations as a result of perceptual deficiencies that effectively add to the convincingness of stimuli when no object is present. In this representation, the criterion and the distribution when real objects are present is the same as that shown in
Figure 1a for normal individuals, so the proportion of veridical perceptions (hits versus misses) remains the same. There is simply less discriminability between the distributions, resulting in more hallucinations.

In Figure 1c we propose a possible alternative representation that produces increased RCVH without requiring perceptual deficiency, instead doing so by having a more liberal criterion for perceiving objects than that of the normal person in Figure 1a. This more liberal location of the criterion line reflects an observer with an attentional mechanism capable of perceiving signals in the more subtle range of available ambient stimuli. Although this criterion shift increases the rate of hallucinations compared to a typical person, it is potentially advantageous, in that the region of misses or lack of awareness of real objects is made notably smaller resulting in a corresponding increase in perception of weakly indicated objects. Thus, there is a new enhanced region of perception within the signal + noise distribution, lying between the normal and more liberal criterion lines (shown as shaded blue in Figure 1). The importance of clarifying this alternate model for increased hallucinations is that it acknowledges the potential for a population of individuals who experience more frequent RCVH than the typical person, yet who are not only not perceptually deficient, but rather individuals who might more accurately be described as perceptually enhanced and more aware of subtle perceptual information. A plausible explanation for such a shift in perception/attention is based on research on the role of attention in visuo-spatial working memory (Pringle et al. 2004). Specifically, attentional processes determine which parts of the immediate environment are stored explicitly or implicitly in memory. We posit that in an individual with a liberal criterion, the explicit-to-implicit ratio is biased toward formation of more explicit memories, thereby resulting in conscious awareness of a larger proportion of the signals in the surrounding environment, as well as enhanced or shifted perception.
The PAD model of RCVH is well thought out and adequately accounts for hallucinations in a pathologic population. However, we suggest the model could be improved by acknowledging that some RCVH may not be pathologic, but rather could be by-products of a more liberal criterion in interpreting weakly indicated stimuli as veridical objects. Furthermore, this liberal criterion can be adaptive in that it reduces perceptual errors of omission of real objects, resulting in an enhanced perception and awareness of subtle real objects and events in the environment.

Footnotes
1. The cost of experiencing RCVH must be outweighed by the benefit of an increased number of veridical percepts.

References


Still PADing along.

Response by Daniel Collerton, Elaine Perry, and Ian McKeith

Abstract: Commentators agree that the Perception and Attention Deficit model (PAD) is a promising model for accounting for recurrent complex visual hallucinations across several disorders though with varying detailed criticisms. Its central tenets are not modified, but further consideration of generative models of visual processing and the relationship of proto-objects and memory systems allows the PAD model to deal with variations in phenomenology. The commentaries suggest new ways to generate evidence that will test the model.

Dolgov & McBeath use signal detection theory to show that hallucinatory perceptions need not always be associated with relatively poorer perception. This is a striking reminder of the multiplicity of ways in which a complex, dynamic set of systems may produce an erroneous result and usefully broadens our perspective to include not just deficit models. However, this specific relationship is mainly likely when the noise and true distributions are highly overlapping (their Fig. 1). Both erroneous “hits” and “misses” are improbable in normal sensory function; otherwise, we would not have functional sensory systems. We therefore suspect that these distributions are usually highly separated. They do overlap when perception is impaired, hence the association within the PAD model of perceptual impairments and hallucinations. In this case, higher rates of hallucinations may be a trade off to reduce agnosia. This is a fascinating possibility that merits further investigation.