Reconciling current approaches to blindsight

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A B S T R A C T

After decades of research, blindsight is still a mysterious and controversial topic in consciousness research. Currently, many researchers tend to think of it as an ideal phenomenon to investigate neural correlates of consciousness, whereas others believe that blindsight is in fact a kind of degraded vision rather than "truly blind". This article considers both perspectives and finds that both have difficulties understanding all existing evidence about blindsight. In order to reconcile the perspectives, we suggest two specific criteria for a good model of blindsight, able to encompass all evidence. We propose that the REF-CON model (Overgaard & Mogensen, 2014) may work as such a model.

1. Introduction

Blindsight is one of the most intriguing yet mysterious phenomena in consciousness research, as well illustrated by the fundamentally self-contradictory term itself. The term refers to a "visual capacity in a field defect in the absence of acknowledged awareness", as defined by Larry Weiskrantz (1986). The phenomenon as such has been described as everything from the most important contribution from experimental psychology to philosophy of mind (Holt, 2003; McGinn, 1991) to nothing but the result of poor measurement (Campion, Latto, & Smith, 1983).

The evidence behind the idea that blindsight exists is a relatively large number of experiments on a very limited number of patients. In particular, the preserved visual functions of patients GY and DB have been studied extensively resulting in several observations of their ability to correctly detect objects or discriminate shapes, brightness, or color presented to a part of their visual field (Cowey, 2010; Weiskrantz, 1986).

Regardless of several more recent experiments with more modern techniques, the "classic" blindsight experiment is arguably Weiskrantz, Warrington, Sanders, and Marshall's (1974) study of DB. In the first of five experiments, DB was asked to shift his eyes from a fixation point to the position he would guess a light was flashed. The second experiment was very similar to the first, except DB now had to reach for the target with a finger instead of relying on eye movements alone. With this different method, results showed a very clear correspondence between target and finger position, especially for larger stimuli. Experiment 3–4 studied DB's ability to discriminate between two possible stimuli (X vs O, horizontal vs vertical lines etc) and found that he was able to do so well above chance level with increased performance as a function of stimulus size. Experiment 5 looked at color discrimination, where DB was to decide whether red or green was presented, but was inconclusive because of technical issues with stimulus control.

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2. Blindsight type 2

Although the key feature of blindsight – the thing that makes blindsight “blind” – is the total absence of “acknowledged awareness”, most blindsight patients have reported particular kinds of “feelings” when presented with visual stimuli (Weiskrantz, 1986). The blindsight literature is riddled with notes and comments about conscious experiences had by the patients during the experimental procedures. Some of these reports refer to “feelings” (e.g. Weiskrantz et al., 1974), yet other seem to refer to some sort of perceptual content, e.g. “visual pin pricks” (Richards, 1973) “dark shadows” (Barbur, Ruddock, & Waterfield, 1980) or “white halos” (Pererin & Jeannerod, 1978). A particularly interesting aspect of these reports is their relation to the objective performance of blindsight patients. It is surprisingly unexplored in the literature, and therefore difficult to seriously discuss, yet there are a few findings of relevance. For instance, in the above-mentioned experiment by Weiskrantz et al. (1974), DB reported “a stronger feeling of something being there” for green compared to red stimuli. The reports correlated with performance, so that DB performed better for green rather than red stimuli.

The fact that blindsight patients seemingly sometimes report experiences could arguably have let researchers to re-evaluate blindsight as distorted or degraded vision, a kind of perceptual dysfunction, rather than the total lack of visual consciousness.

The difference between the two interpretations is big. Blindsight would in both cases be interesting in consciousness research, but in very different ways. In the “classical” interpretation – that blindsight is subjectively blind – one might consider blindsight a “pure contrast”, i.e. that the contrast between normal, conscious perceiving and blindsight may reveal neural correlates of visual consciousness. This approach is suggested by Lau and Passingham (2006). In the other interpretation – that blindsight is distorted perception – the phenomenon obviously cannot be considered a “pure contrast”, and thus, it will inform models of neural correlates of consciousness differently.

The argument that blindsight is perceptual dysfunction is rarely seen. Instead, for most blindsight researchers, the definition of “blindsight” has remained unchanged, and the instances of reported subjective experiences in the patients are argued to reflect a “blindsight type 2”. Blindsight type 2 is considered to be a case of experiencing a “feeling” or “knowing” of something that was visually presented, yet without any visual experience.

Below, the two positions are investigated further. The intention is not to provide a comprehensive review of the blindsight literature which has been done elsewhere (Cowey, 2010) but rather to evaluate arguments for and against the two positions.

3. The classical interpretation: two kinds of blindsight

Blindsight type 1 is relatively well-defined by Weiskrantz as a “visual capacity in a field defect in the absence of acknowledged awareness”. The definition does not explicitly involve injury to the primary visual cortex, although this is often implicitly assumed. Nevertheless, the term is sometimes used to denote other kinds of unconscious perception, even in healthy subjects (e.g. Roseboom & Arnold, 2011). Common for these different variations, though, is the conviction that blindsight type 1 is a total absence of any conscious experience in a (part of the) visual field without a total lack of perceptual function.

Blindsight type 2 has a somewhat less clear definition. As stated above, it involves “feelings” associated with the visual capacity without these feelings are visual. Obviously, it is absolutely crucial for the definition to have any bearing that the experiences (“feelings”) are not visual, but this is not easily done. In order to do so, one must have a criterion (or set of criteria) to determine whether something is visual or something else.

It is important to note that the two types of blindsight cannot denote different syndromes in a normal sense, as they do not point out two different groups of patients. Studies of DB and GY, for instance, are the main sources of evidence for both type 1 and type 2, and, obviously, the same neural injuries seem to give rise to both phenomena. GY and DB seemingly sometimes report “feelings”, and sometimes to experience nothing at all under the same stimulus conditions (e.g. Weiskrantz et al. (1974)). Accordingly, the two types of blindsight must relate to two types of mental contents, and not different persons.

Persaud and Lau (2008) gave GY philosophical articles about qualia from The Standford Encyclopedia, The Oxford Companion to the Mind and by Jackson (1982), and Daniel Dennett’s book Consciousness Explained (1991). Persaud and Lau asked GY if he ever had qualia in his scotoma in an interview with several subquestions. GY, who is very well informed about blindsight, acknowledged that he had qualia in his intact field but stated that he did not have qualia in his scotoma, even under conditions where he was aware of something being present. Persaud and Lau conclude on this basis that GY does not have conscious visual experiences in his scotoma, but, instead, “non-visual” experiences.

This conclusion is only warranted if GY’s verbal denial of having qualia (1) only applies to visual qualia, and (2) must lead us to conclude with necessity that he in fact does not have visual experiences (Foley, 2012). However, if assuming the existence of blindsight type 1, one is faced with a dilemma: Either the criterion for “visual capacity” is not introspective (and, in such case, the verbal categorization as “visual” or “not visual” by GY or other blindsighters is not sufficient), or the criterion is in fact introspective (and, in such case, there can be no such thing as unconscious vision, and therefore, no such thing as blindsight type 1).

Unconscious visual perception, including blindsight type 1, is established whenever a subject is able to react to a visual stimulus. Consequently, one would say, a visual process is one in which a subject at some level reacts to something visual. From this argument it should follow that if there is any kind of preserved conscious experience in blindsight subjects caused
by visual stimuli, as would be the case with blindsight type 2, those experiences could logically be conceived of as visual (see discussion in Brogaard, 2011; Overgaard & Grünbaum, 2011).

As long as the debate over criteria for when something is visual is ongoing, one cannot simply assume that experiences reported as evidence for blindsight type 2 are non-visual. Consequently, one cannot assume that blindsight type 2 exists at all.

4. The alternative interpretation: blindsight as perceptual dysfunction

This interpretation takes the opposite direction than the “classical interpretation” to explain the reported “feelings”. It argues that there are not two kinds of blindsight, just one kind that involves distortions of normal perception due to brain injury and post-lesion neuroplastic changes.

The position seems to imply that experiences in blindsight are in fact visual, i.e. that even if it involves some kind of distorted experience that is unlike normal perception, it is visual perception nonetheless. The argument is difficult as it goes against much evidence in blindsight research. As one example, how should one argue against GY’s reports in the interview performed by Persaud and Lau (2008).

In one experiment, Stoerig and Barth (2001) investigated reported “feelings” in GY in order to see if they were somehow low-level perceptual in nature. To do so, GY was asked to match a visual stimulus presented in the scotoma with one of different image transformation of the same stimulus in the healthy field. When using high-contrast stimuli, GY deemed the stimuli as “visual” and accordingly as “no match at all” compared to the “feeling” in the blind field. However, with moving stimuli, GY accepted the match as long as they were sufficiently blurred and appeared as “motion only”. The results match with GY’s verbal descriptions of his “feelings” as “similar to that of a normally sighted man who, with his eyes shut against sunlight, can perceive the direction of motion of a hand waved in front of him” (Beckers & Zeki, 1995, p. 56). Stoerig and Barth conclude that even though GY’s vision is clearly degraded and different from normal vision, his experiences are still basically visual in nature.

The experiment by Stoerig and Barth seems to support this alternative explanation but it offers no explanation of the conflicting evidence. Why would the same person, GY, refuse ever having visual qualia in the scotoma in an interview, yet describe stimuli as “visual” in a different study?

Overgaard, Fehl, Mouridsen, Bergholt, and Cleeremans (2008) performed a study on a 31-year old hemianopic patient with left-sided injury to primary visual cortex (GR). In the first experiment, letters were briefly flashed at different locations on a computer screen and GR’s only task was to respond to every stimulus, revealing that she was blind to everything presented in the upper right quadrant. In a second experiment, GR was presented with different visual figures and asked 1) which figures were shown, and 2) if she actually saw the figure – yes or no. GR reported only very rarely that she saw stimuli in the upper right quadrant, yet she was able to report correctly about these stimuli more often than chance. In the healthy part, her reports were significant predictors of correctness, based on which the authors concluded that she had blindsight. The third experiment was identical to the second, except she now should respond with PAS (the Perceptual Awareness Scale with four labelled points) rather than in a binary fashion. As a consequence, her blindsight seemingly “disappeared” in the sense that, even though she reported much more vague experiences in the upper right compared to the upper left quadrant, the relationship between correctness and reported experience was identical to what was found within the rest of the visual field. All correctness above chance seemed related to vague yet conscious vision when using PAS. So, the first experiment indicates that GR is a “cortically blind hemianopic”, the second experiment indicates that she has blindsight, perhaps, type 1, and the third that she has blindsight type 2 if blindsight at all. However, such conclusion is challenged by the note above that the two “types” of blindsight do not refer to different syndromes.

The result of the study by Overgaard et al. (2008) offers one possible response to the question above: that reports about consciousness are different from our everyday uses of the term, and that proper reports require some training. It should also be remembered that GY in the study by Persaud and Lau (2008) was given Daniel Dennett’s definition of qualia (Dennett, 1991) which many philosophers consider very narrow and “private”. The PAS was first developed by Ramsøy and Overgaard (2004) who asked subjects to create their own scale for subjective report with the instruction that they should be able to subjectively experience the difference between the scale points, they invented. Most subjects conformed to a four-point scale with categories such as ‘not seen’, ‘weak glimpse’ (meaning ‘something was there but I had no idea what it was’), ‘almost clear image’, and ‘clear image’. A number of studies using PAS, leading up to the study of GR, showed a good correlation between PAS reports and correctness (Ramsøy & Overgaard, 2004; see Overgaard & Sandberg, 2012 for a review). Crucially, it was repeatedly found that reports not to see anything according to PAS and a dichotomous scale, respectively, were associated with significantly different response patterns. Participants that used PAS and reported not to see the stimulus at all performed at chance level. But participants were under the very same experimental conditions responding much above chance level when reporting not to be conscious of the stimulus using a dichotomous scale (Overgaard, Rote, Mouridsen, & Ramsøy, 2006). One conclusion to be drawn from this is that the way in which participants are asked to report about their experiences give rise to different results. The distinction between “not seen” and “brief glimpse” is typically the one that most participants confuse in the beginning of experiments. “No experience” is defined as having no subjective experience of the stimulus, not even the “faintest sensation” that anything was presented at all. Not even a feeling that something might have been presented. “Brief glimpse” is defined as a variation in subjective experience that is
achieve a task solution similar to what is seen in intact individuals — but using different task solution strategies (e.g., in the area of problem solving, experimental animals lacking the hippocampus or the prefrontal cortex are able to arrive at a solution equally proficient to what is seen in intact individuals [e.g., Mogensen & Malá, 2009; Mogensen et al., 2004]. For such a "module" has been completely removed bilaterally — posttraumatic rehabilitative training of a cognitive task can lead to the area can be re-established after training. In animal models — where a brain structure and thereby the neural substrate of neuroscientific models have tried to reconcile the facts that (1) there seems to be functional localization in the brain, and (2) posttraumatic functional recovery is possible. In "classic" modular theories of the brain (e.g., Fodor, 2000; Pinker, 1999), it seems impossible that a human or animal can "lose" a part of the brain, and, at the same time that functions associated with that area can be re-established after training. In animal models — where a brain structure and thereby the neural substrate of such a "module" has been completely removed bilaterally — posttraumatic rehabilitative training of a cognitive task can lead to a solution equally proficient to what is seen in intact individuals [e.g., Mogensen & Malá, 2009; Mogensen et al., 2004]. For example, in the area of problem solving, experimental animals lacking the hippocampus or the prefrontal cortex are able to achieve a task solution similar to what is seen in intact individuals — but using different task solution strategies (e.g., Mogensen et al., 2004).

We (e.g., Mogensen, 2011c, 2012; Overgaard & Mogensen, 2011) suggest that the term "functions" in cognitive science should be understood at different levels of analysis. We may speak of a "cognitive domain" as a general, functional manifestation level such as "visual perception", or of "task- and domain-specific functions" as functions related to a particular way of realizing or using functions at the most general level. Finally, we may speak of "basic functions" understood as basic-level operations that may only be described in mathematical terms. Whereas the experimental animals from the example above were able to perform "problem solving" just like intact control animals, their strategy (or "task-specific functions") were different. That is, it seems to be the case that whether two functions are the same or different depends on the level of analysis.

6. REF-CON

The REF-CON model has been proposed by Overgaard and Mogensen (2014) in the attempt to fit a neuroscientific model to the above-mentioned levels of analysis. REF-CON is built on the basis of the REF-model (e.g., Mogensen, 2011a, 2012; Mogensen & Malá, 2009). The REF-model essentially describes a connectionist network in which, however, the "units" are not neutral and functionally indifferent "neurons" — but advanced information processing modules called Elementary Functions. REF is thus able to account for both the localization and posttraumatic recovery of functions. In REF, the "upper level" is the surface phenomenon — a particular behavior or mental state. The lowest level is the Elementary Functions. Bridging between the upper and lower levels of surface phenomena and Elementary Functions, respectively, a level of Algorithmic Strategies constitutes the cognitive "programs" giving rise to the individual surface phenomena. Elementary Functions perform basic information processing and are localized within restricted subdivisions of neural structures. In contrast, Algorithmic Strategies consist of numerous interacting Elementary Functions and are distributed in the sense that the neural
The REF-CON model is described in more detail in Overgaard and Mogensen (2014). For the present purpose, REF-CON is briefly described and presented as an approach to understanding the dilemmas regarding blindsight, as presented above. The REF-CON model is based on the same types of Elementary Functions, Algorithmic Modules and Algorithmic Strategies as the original REF-model. A crucial element within the mechanisms of REF-CON is the Perceptual Elementary Function, which differs from other Elementary Functions by receiving a more or less direct sensory input. “Ordinary” Elementary Functions have no functional specificity reaching beyond their basic information processing. The association of an Elementary Function with a particular cognitive domain is determined by the changing input/output relationships of the Elementary Function. In contrast, a Perceptual Elementary Function is “prewired” to be associated with a sensory modality and thus with a perceptual analysis.

The Perceptual Elementary Functions are likely to be localized at subcortical as well as cortical levels (in case of vision in the V1/V2 region) and are the initial central processing steps for the incoming sensory information (which has been processed peripherally before reaching the Perceptual Elementary Functions of the brain – visual information has, for instance, undergone an extensive processing within the retina).

An important mechanism of the perceptual process is the activation of Perceptual Algorithmic Modules. These modules are hierarchically arranged and normally a perceptual analysis progresses through a substantial number of layers of Perceptual Algorithmic Modules. When a pattern of activation of Perceptual Elementary Function occurs, the activated Perceptual Elementary Functions will lead to a degree of activation of a number of Perceptual Algorithmic Modules of the lowest level of this hierarchy. When thus activated, each of these Perceptual Algorithmic Modules “interrogates” its constituent Perceptual Elementary Functions as to its level of activation. Out of the activated Perceptual Algorithmic Modules, the one which in such an interrogation reaches the highest level of correspondence between constituent and activated Perceptual Elementary Functions, respectively, is the one to reach a full level of activation. Within the hierarchically organized Perceptual Algorithmic Modules, the modules at the lowest level are constituent elements within higher levels. As the perceptual process progresses through the levels of Perceptual Algorithmic Modules, the selection process is similar to the one determining which Perceptual Algorithmic Module of the lowest level becomes activated: the activated modules at a given level “interrogates” their constituent components as to their degree of activation. Only the Perceptual Algorithmic Modules of the highest level of the above-described hierarchy are (potentially) available to the regulation of behavior and/or conscious experience.

The Perceptual Algorithmic Module of the highest level will, when fully activated, potentially become integrated into a special type of Algorithmic Strategy named the Situational Algorithmic Strategy (SAS). The SAS is a highly dynamic network, reflecting the current status of the individual. The SAS combines elements within sensory/perceptual, motor/behavioral, motivational/planning and other systems. Only when integrated into the network of SAS, will a Perceptual Algorithmic Module of the highest level be available for behavioral control and potentially for conscious awareness. The degree and pattern of the integration into SAS determines the level of availability to conscious awareness.

From the perspective of REF-CON, the injury to V1/V2 in blindsight is an injury of the neural substrates of Perceptual Elementary Functions crucial to vision. In such a situation, however, preserved Perceptual Elementary Functions (cortical and/or subcortical) may still lead to activation of Perceptual Algorithmic Modules – although activating patterns and modules different from those which would have been the case without the injury.

The somewhat rudimentarily analyzed visual information available in blindsight is according to the REF-CON framework – a reflection of a process in which the visual analysis has progressed through only a relatively low number of levels of Perceptual Algorithmic Modules. Therefore, the analysis will reach its most advanced level, the highest level, at a comparably earlier stage of analysis than what is normally seen. Although these earlier levels can become integrated into the SAS (and thereby made available to behavioral control) such a process requires an unusual degree of top-down control and effort.

The fact that the same blindsight patients may over time – and to an extent in a situationally dependent manner – exhibit different levels of conscious awareness of the visually presented stimuli, can according to the REF-CON model (besides potential methodological issues) be explained as dynamically changing degrees of integration of Perceptual Algorithmic Modules into SAS. Different situational demands (and thus even different experimental setups) can be expected to cause such modifications in network-integration. If, for instance, two experimental situations differentially emphasize the importance of availability of the visually presented stimulus, a higher degree of integration into SAS will be expected in the situation with the higher level of emphasis on having the information available for behavioral control and/or conscious awareness. Such an emphasis may either grow implicitly out of the experimental design or be explicitly presented by an experimenter. Training and learning processes are other factors to be taken into consideration. Both in animal models (Dineen & Keating, 1981; Humphrey, 1974) and in blindsight patients (Bridgeman & Staggs, 1982; Chokron et al., 2008; Henriksson, Raninen, Näsänen, Hyvärinen, & Vanni, 2007; Raninen, Vanni, Hyvärinen, & Näsänen, 2007; Stoerig, 2006; Zihl, 1980; Zihl & Werth, 1984) training can increase the degree to which stimuli are available to behavioral control and potentially even to subjective awareness (Sahraie et al., 2006). Viewed from this perspective, a differentiation between
blindsight of type 1 and type 2 can be viewed as a differentiation between dynamically changing and both situationally and experience-dependent differences in the network integration of Perceptual Algorithmic Modules within SAS. And the differentiation between patients exhibiting blindsight and similarly injured patients without blindsight may be interpreted in a similar manner. Since blindsight is only demonstrated when prompting and top-down effort is present, one may see the absence of blindsight in individuals suffering injury to the primary visual cortex as reflecting lack of training and provocation rather than as a consequence of the nature of the injury.

Empirical support to such an idea comes from many experiments in humans and animals, and even in blindsight patients. In a forced choice procedure, performance can be improved by training in both monkeys subjected to bilateral ablation of the primary visual cortex (V1) (Dineen & Keating, 1981; Humphrey, 1974) and patients demonstrating blindsight (e.g. Bridgeman & Staggs, 1982; Chokron et al., 2008; Henriksson et al., 2007; Raninen et al., 2007; Stoerig, 2006; Zihl, 1980; Zihl & Werth, 1984). In blindsight patients, training may not only improve the behavioral performance but also the subjective awareness (e.g. Sahraie et al., 2006).

So, from this perspective, what we call blindsight would most likely still be visual perception, and visual experience whenever there is an accompanying experience, at the surface level of analysis. However, from the lower levels of analysis, Perceptual Elementary Functions and Perceptual Algorithmic Functions, it may be rather different from normal visual perception.

As described above, the degree to which blindsight patients report what they experience as “visual” or not may differ over time and in a situationally dependent manner. One of the factors contributing to such differences may be dynamic reorganizations within the Perceptual Algorithmic Modules. Examples of similar reorganizations may be found within the somatosensory system of individuals in which a bodypart – for instance a hand – has been amputated. After the amputation of a hand, its representation within the somatotopic representation is initially “vacant”. But subsequent dynamic reorganizations leads to the previous hand area being cannibalized by the neighboring areas of the somatotopic map – representing the arm and face, respectively (e.g. Karl, Birbaumer, Lutzenberger, Cohen, & Flor, 2001; Weiss et al., 2000; Yang et al., 1994). Thus, this reorganization causes the substrate of the Perceptual Elementary Functions of the previous hand area to now receive inputs from the face or arm. Nevertheless, peripheral stimulation activating these “reassigned” Perceptual Elementary Functions will still for a period of time give rise to a subjective experience of stimulation of the absent hand (e.g. Kaas, 1998; Knecht et al., 1996). Only with additional “training” – and according to the REF-CON model reorganization of Perceptual Algorithmic Modules – will the subjective experience reflect the actual pattern of peripheral stimulation. In at least some cases of cross-modal plasticity one may find processes of a somewhat similar nature even crossing the divisional lines between modalities. “Prosthetic” vision via somatosensory stimulation may in early-blind individuals be experienced as being of a more “visual” nature when compared to the experience of similar stimulation in blindfolded sighted individuals (e.g. Pito, Moesgaard, Gjedde, & Kupers, 2005). While the question of whether or not experiences of blindsight patients are of a “visual” character or not may be partly an issue of semantics as well as experimental methods, it may also represent variations (even within the same individual) of the structure of the constantly reorganizing Perceptual Algorithmic Modules.

The REF-CON perspective explains why blindsight patients do not consider their experiences “visual” as they in fact are different from “normal” visual perception. Some evidence for this explanation comes from Azzopardi and Cowey (1997) who performed a signal detection analysis on GY’s yes/no-detection judgments and forced-choice detection tasks and found that his sensitivity was significantly higher during the forced-choice task. This is different from the performance of healthy subjects when having “near-threshold vision”, indicating that visual stimuli in blindsight are processed “in an unusual way” (Azzopardi & Cowey, 1997, p. 14190). At the same time, the REF-CON perspective explains why blindsight patients do have “visual descriptions” of visual stimuli as the blindsighter’s experiences reflect visually presented stimulus properties. As in Overgaard et al’s (2008) study of GR, the patient has fewer and more vague visual experiences of stimuli in the scotoma.

7. Conclusions

Blindsight is still a very controversial topic, not least the phenomenon “blindsight type 2” that challenges the idea of “blind sight” in a fundamental way. One can, at least, distinguish between two major approaches to the topic: One, according to which blindsight is an example of a “pure contrast” between consciousness and performance, and, furthermore, blindsight type 2 is non-visual consciousness caused by visual stimuli. According to the other approach, blindsight is essentially a result of underdeveloped methodology, blindsight should be seen as degraded vision.

The major problem with these two approaches is that they are perfectly suited to explain parts of the data from blindsight research, yet are “blind” to other parts. For this reason, we have argued that a good explanation of blindsight must be able to explain (1) why blindsight patients do not consider their experiences evoked by visual stimuli as experiences of a visual nature, and (2) why blindsight patients still report experiences that seem to have visual qualities and why such reports, at least sometimes, correlate with clarity of experience.

To do so, we have described aspects of the REF-CON model that has been developed as a framework to understand the relation between mental representation, conscious experience, and neural underpinnings. We believe that REF-CON potentially can play this role of reconciling the approaches to blindsight, although this is still work in progress.
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