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Relative blindsight arises from a criterion confound in metacontrast masking: Implications for theories of consciousness

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ABSTRACT

Relative blindsight is said to occur when different levels of subjective awareness are obtained at equality of objective performance. Using metacontrast masking, Lau and Passingham (2006) reported relative blindsight in normal observers at the shorter of two stimulus-onset asynchronies (SOAs) between target and mask. Experiment 1 replicated the critical asymmetry in subjective awareness at equality of objective performance. We argue that this asymmetry cannot be regarded as evidence for relative blindsight because the observers' responses were based on different attributes of the stimuli (*criterion contents*) at the two SOAs. With an invariant criterion content (Experiment 2), there was no asymmetry in subjective awareness across the two SOAs even though objective performance was the same. Experiment 3 examined the effect of criterion level on estimates of relative blindsight. Collectively, the present results question whether metacontrast masking is a suitable paradigm for establishing relative blindsight. Implications for theories of consciousness are discussed.

1. Introduction

Studies of the neural correlates of consciousness often rely on two types of responses: objective performance on the task at hand and reports of subjective awareness[1] (see Dehaene & Changeux, 2011 for a review). The finding that objective performance in a forced-choice task can be relatively high in the absence of subjective awareness is called *blindsight* as evidenced in patients with lesions in primary visual cortex (Weiskrantz, 1999; but see Overgaard, 2011, and Overgaard, Fehl, Mouridsen, Bergholt, & Cleeremans, 2008). A related concept called *relative blindsight* was introduced by Lau and Passingham (2006) to denote the finding that different levels of subjective awareness can be obtained in healthy observers even at equality of objective performance. Notably, relative blindsight is said not to involve any neurological deficit. Here we question the validity of the paradigm used in Lau and Passingham's study, and hence the inferences drawn from the experimental outcomes.

Lau and Passingham (2006) employed a metacontrast masking paradigm to measure both objective performance and subjective awareness. In this paradigm, a briefly-displayed target is followed by a masking stimulus whose contours are closely adjacent to – but do not overlap with – the contours of the target. The temporal signature of metacontrast masking is a U-shaped function relating the accuracy of target identification to the stimulus-onset asynchrony (SOA) between the target and the mask (Breitmeyer & Öğmen, 2006; Di Lollo, von Mühlenen, Enns, & Bridgeman, 2004). At very short or very long SOAs, the target is identified easily. At intermediate SOAs, however, perception of the target is impaired, leading to the characteristic U-shaped function.

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[1] It can be argued that subjective awareness cannot be examined directly because of lack of direct phenomenological access to first-person perspective (obviously, this does not apply when the experimenter and the observer are one and the same). On this view, what is being studied is the observers' *meta-awareness*, namely their judgments of their own awareness.

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The stimuli used in Lau and Passingham's (2006) study are illustrated in Fig. 1a, and the essential aspects of the results are illustrated in Fig. 2a, redrawn from Fig. 2 of Lau and Passingham. The observers were required to make two responses. First they identified the target shape ("Square or Diamond?") and then they reported whether they had consciously perceived the target or had made a guess ("Seen or Guessed?"). The principal objective was to single out two experimental conditions in which the accuracy of target identification was the same but the reports of subjective awareness differed. This was achieved by varying the temporal relationship between the target and the mask over a wide range of SOAs. The critical finding concerned the results at two SOAs: 33 and 100 ms. As indicated by the two segmented ovals in Fig. 2a, the levels of objective performance were approximately the same at the two SOAs, but the level of subjective awareness was significantly lower at the shorter SOA. Lau and Passingham interpreted this asymmetry in subjective awareness as an instance of relative blindsight at the shorter SOA and concluded that different levels of visual awareness can be attained even at equality of objective performance.

This interpretation is questionable, however, on the grounds that the attributes of the display on which the observers based their responses were demonstrably not the same at SOAs of 33 and 100 ms. An example will clarify this issue. Illustrated in Fig. 1b and c is the appearance of the display at short and at long SOAs, respectively. In Fig. 1b the target and the mask are seen as forming a single, temporally-integrated image. Because of the relatively poor temporal resolution of the visual system – relative to, say, the auditory system – two brief stimuli displayed in rapid succession are perceived as a single image. This has been studied using a 5 $\times$ 5 dot-matrix with one dot missing at a random location (Di Lollo, 1980; Dixon & Di Lollo, 1994). To study temporal integration, the matrix is presented in two successive sets of 12 randomly-chosen dots each, separated by a variable SOA. At short SOAs (e.g., up to about 40 ms), the two percepts are temporally integrated, and the task of locating the missing dot is compellingly easy, with near-perfect performance. At longer SOAs (beyond about 100 ms), the two sets of dots are increasingly perceived as temporally distinct, with performance approaching chance level. Notably, Dixon and Di Lollo (1994) have shown that at the stimulus durations employed by Lau and Passingham (2006) two sequential stimuli are integrated maximally at the shorter SOA (33 ms), but to a much lesser extent at the longer SOA (100 ms).

A notable aspect in Fig. 1b is that at the shorter SOA the target was defined not by luminance contours but by the presence of four little black triangles that acted as inducers in a Kanizsa figure (Kanizsa, 1955). Thus, the observer's response was based not on direct perception of the target shape but on an inference stemming from the geometrical arrangement of the four little triangles. To be clear about this, target identification at short SOAs would have been near chance level but for the presence of the four little triangles representing the portions of the background remaining visible through the mask. This was clearly not the case at longer SOAs at which the luminance-defined target shape was perceivable directly (Fig. 1c).

In more abstract terms, it can be said that the observers' responses at the short and the long SOAs were based on different criterion contents. Kahneman (1968) introduced the term *criterion content* to denote the attributes of a stimulus on which an observer bases the perceptual decision. It is well-known that in masking experiments the criterion content can vary systematically with SOA (Kahneman, 1968; Sperling, 1965). With reference to Lau and Passingham's (2006) study, the criterion content at the short SOAs was mainly the target shape inferred from the little triangles provided by the temporal integration of the target and the mask. In contrast, at the long SOAs the criterion content was the luminance-defined target shape itself. Because they were based on different criterion contents, estimates of both objective performance and subjective awareness were not entirely comparable across short and long SOAs.

How the different criterion contents might have influenced the asymmetry in subjective awareness at the two SOAs (given equality of objective performance) is not immediately obvious. A plausible account can be given on the twin assumptions that (a) objective performance depends on the availability of either of the two attributes of the display (little triangles or luminance-defined shape), and (b) subjective awareness (the observer's willingness to admit to having seen the target's shape rather than having guessed it) depends on the salience (i.e., prominence or discernibility) of that attribute. Based on the first assumption, the two attributes could mediate equal levels of performance at SOAs of 33 and 100 ms. Based on the second assumption, it is conceivable that the salience of the little triangles at the shorter SOA was less than the salience of the target shape at the longer SOA. This would reduce the observers' confidence in their acknowledgment of actually having seen the target, i.e., in their level of meta-awareness.

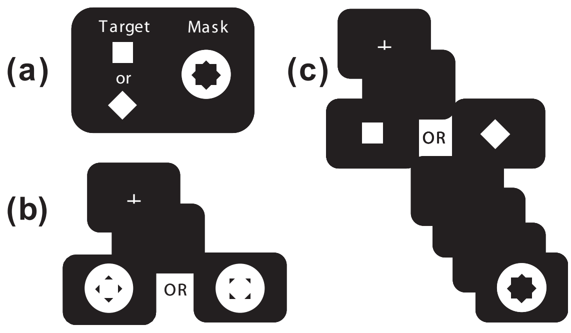

Fig. 1. (a) Target and masking stimuli employed in Experiment 1 and in Lau and Passingham's (2006) experiment. (b) Appearance of the temporally-integrated target and mask at short SOAs. (c) Appearance of the temporally-segregated target and mask at long SOAs.

We hasten to add that, while plausible, this account is clearly speculative. The fact remains, however, that different criterion contents mediated the responses at the short and at the long SOAs in Lau and Passingham's (2006) experiment. What needs to be done is to determine whether the asymmetry in subjective awareness still occurs with a metacontrast paradigm in which performance is based on a single criterion content throughout the SOA domain. This was done in the present work by replicating the study of Lau and Passingham in Experiment 1 and then repeating the experiment with a metacontrast masking paradigm in which a single criterion content mediated the responses at all SOAs.

2. Experiment 1

2.1. Method

2.1.1. Participants

Thirty undergraduate students at Simon Fraser University participated for course credit. All reported normal or corrected-to normal vision and were naïve to the purpose of the experiment.

2.1.2. Stimuli and procedures

The stimuli, illustrated in Fig. 1a–c, and the procedures were the same as those used by Lau and Passingham (2006). The experiment was run in a dimly lit room. Observers sat at a distance of approximately 60 cm from a CRT computer screen (NEC AccuSync 120) refreshed at a rate of 140 Hz. At the beginning of each trial, a white fixation cross (0.5°) was displayed at the center of the black screen (.02 cd/m^2). The target was either a white square (1°) or a white diamond (i.e., a square of the same size rotated by 45°) presented at the center of the screen for 35 ms at a luminance of 95 cd/m^2, and was randomly chosen on each trial. The mask (Fig. 1a) subtended 2° and was displayed for 50 ms. The inner contours of the mask abutted the contours of the target. There were eight target-mask SOAs: 0, 21, 35, 42, 63, 84, 105, and 126 ms.

Participants initiated each trial by pressing the spacebar. Following the display sequence, the question "Diamond or Square?" (or "Square or Diamond?", counterbalanced across participants, 1° in height) was displayed 3° above the center of the screen. Participants responded by pressing the corresponding mouse button. Next, a second question was displayed 3° below the center of the screen: "Seen or Guessed?" to which participants responded by pressing the left mouse button if the target was actually consciously perceived and the right mouse button if it was not and the previous response was based on a guess. After the response, the fixation cross reappeared indicating readiness for the next trial. The trial ended at 3650 ms after the beginning. If participants failed to respond to both questions after this time, the question disappeared, the trial was discarded and the fixation cross was displayed after a 350-ms inter-trial interval. Participants were instructed that accuracy rather than speed was important, provided that they responded to both questions within the time allowed. There were 84 trials at each SOA, sequenced randomly. The participants could take a break at any time between trials.

2.2. Results and discussion

Fig. 2b illustrates the mean results for objective performance and subjective awareness. A repeated-measures analysis of variance (ANOVA) revealed significant effects of SOA, $F(7,203) = 23.76$, $MSE = 161.6$, $p < .001$, $\eta_p^2 = .45$ and the Measure (Performance/Awareness) × SOA interaction, $F(7,203) = 4.85$, $MSE = 247.0$, $p < .001$, $\eta_p^2 = .14$. The effect of Measure was not

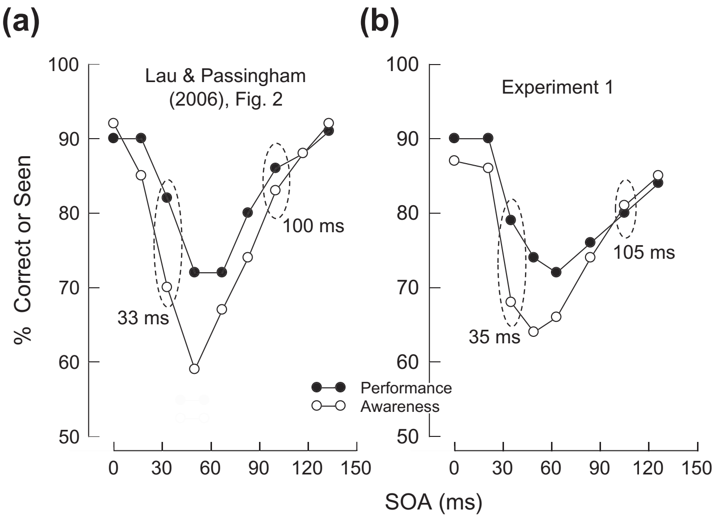

Fig. 2. (a) Results of the Lau and Passingham's (2006) study, redrawn from their figure. (b) Results of Experiment 1. Segmented ovals indicate the two critical SOAs (see text for explanation).

significant, $F(1,29) = 3.28$, $MSE = 664.9$, $p = .08$, $\eta_p^2 = .10$. The important results for the present purpose were at SOAs of 35 and 105 ms, indicated by the segmented ovals in Fig. 2b. There were two critical findings: (a) the level of performance was approximately the same at SOAs of 35 and 105 ms, $t(29) = .58$, $p = .57$, and (b) the level of awareness was significantly lower at an SOA of 35 ms than at an SOA of 105 ms, $t(29) = 3.05$, $p < .005$.

This pattern of results replicates closely the corresponding pattern of results in the study of Lau and Passingham (2006). Experiment 2 was designed to check whether a similar pattern of results – notably the asymmetry in level of subjective awareness across the two critical SOAs – is obtained using a metacontrast masking paradigm in which the responses are based on a single criterion content throughout the SOA domain.

3. Experiment 2

3.1. Method

3.1.1. Participants

Twenty-two observers were drawn from the same population as Experiment 1. None had participated in Experiment 1.

3.1.2. Stimuli and procedures

The stimuli are illustrated in the inset of Fig. 3a. The target, which consisted of two columns of three dots each, subtended 1.2° horizontally and 1° vertically. The mask, which consisted of two sets of two columns of dots that flanked the target columns (Kahneman, 1967; see inset in Fig. 3a), had the same height as the target and subtended 2.4° horizontally. Each dot subtended approximately .04°.

On every trial, one dot was missing from one of the rows in either the left or the right columns of the target. Observers answered the question "Left or Right?" to indicate whether the missing dot was on the left or on the right column by pressing the corresponding mouse button. The target-mask SOA ranged from 0 to 126 ms in steps of 14 ms, with the addition of an SOA of 250 ms. The second question ("Seen or Guessed?") and all other parameters were the same as in Experiment 1.

3.2. Results and discussion

Fig. 3a illustrates the mean results for objective performance and subjective awareness. A repeated-measures ANOVA revealed significant effects of SOA, $F(10,210) = 33.68$, $MSE = 80.24$, $p < .001$, $\eta_p^2 = .62$, and the Measure (Performance/Awareness) $\times$ SOA interaction, $F(10,210) = 3.82$, $MSE = 146.55$, $p < .001$, $\eta_p^2 = .15$. The effect of Measure was not significant ($F < 1$). The significant interaction effect was driven by the finding that, whereas the two functions in Fig. 3a were virtually the same at long and intermediate SOAs, the level of subjective awareness was lower than the level of objective performance at the short SOAs. This could be a consequence of the relatively crowded appearance of the displays at the short SOAs, which allowed accurate performance but impaired the observers' confidence in reporting their subjective awareness.

The important consideration is that, unlike Lau and Passingham's (2006) study in which different criterion contents mediated the responses at the short and the long SOAs (little black triangles and the target shape itself, respectively), here there was only one criterion content (the side of the missing dot) on which to perform the task throughout the range of SOAs. It is also important to distinguish between the functional significance of temporal integration of the target and the mask at the short SOAs in Lau and Passingham's study and in the present experiment. In Lau and Passingham's study, temporal integration gave rise to an additional cue (the little black triangles), that provided a new criterion content and permitted an inference to be made as to the target shape. In contrast, in the present experiment, temporal integration did not give rise to any additional cues from which to infer the identity of the target, leaving a single criterion content on which to base the responses.

As noted in the Introduction, relative blindsight is in evidence when the results at two SOAs exhibit the same level of objective performance but different levels of subjective awareness. Based on this definition, no evidence of relative blindsight was found in the present Experiment. As illustrated in Fig. 3a, there were two pairs of SOAs at which the levels of objective performance matched: one such pair (segmented ovals) comprised SOAs of 28 and 250 ms; the other (segmented rectangles) comprised SOAs of 56 and 112 ms. The critical consideration is that in each pair the level of subjective awareness was also approximately the same. No statistical tests are obviously required for the results at SOAs of 56 and 112 ms (segmented rectangles). A repeated-measure ANOVA performed on the results at SOAs of 28 and 250 ms revealed no significant effects (all *F*s < 1.6). Notably, the awareness scores did not differ between the two SOAs, $t(21) = .52$, $p > .61$. The lack of asymmetry in subjective awareness between the two SOAs in each pair is inconsistent with the occurrence of relative blindsight.

4. Experiment 3

We have noted that the criterion content adopted when carrying out a perceptual task can affect the experimental outcome. The same can be said for the corresponding concept of *criterion level*. As Kahneman (1968) put it, "Specification of *criterion level* answers a quantitative question: How reluctant is the subject to give a particular response?" (p. 410). Given a forced-choice question, such as the "Seen or Guessed?" question in the present work, criterion level is said to be *conservative* when the observers are reluctant to acknowledge having seen the target unless they are quite sure. On the other hand, the criterion level is said to be *liberal* when the observers are willing to acknowledge having seen the target on relatively scant evidence.

A comparison between Experiments 1 and 2 illustrates how measures of relative blindsight are critically dependent on the maintenance of a single criterion content throughout the performance of the perceptual task. It could also be argued that relative blindsight is affected by the criterion level adopted by the observers in any given experiment. The logic behind this argument is not entirely straightforward. It may be claimed, for example, that although a change in criterion level might shift the overall level of the awareness function (e.g. in Fig. 2b), the critical asymmetry that defines relative blindsight could remain unaltered. This argument, however, is based on the assumption that a change in criterion level affects the estimates of subjective awareness equally at all SOAs, which may not be the case. Experiment 3 was designed to examine how adopting a more liberal criterion affects the estimates of subjective awareness and hence the corresponding estimates of relative blindsight.

In Experiment 3 we attempted to implement a more liberal criterion relative to Experiment 2 by making a small change in the instructions. The relevant part of the instructions in Experiment 2 was "Please press the left mouse button if you *actually* saw the target, and the right button if you guessed". In Experiment 3 that instruction was changed to: "Please press the left mouse button if you *think* that you saw the target, and the right button if you guessed" (emphasis not included in the actual instructions).

4.1. Method

4.1.1. Participants

Eleven observers were drawn from the same population as Experiments 1 and 2. None had participated in the previous two experiments.

4.1.2. Stimuli and procedures

Aside from the small change in the instructions, noted above, the stimuli and procedures were the same as in Experiment 2.

4.2. Results and discussion

Fig. 3b illustrates the mean results for objective performance and subjective awareness. The important comparisons are between the results in the present experiment and the corresponding results in Experiment 2 in which a more conservative criterion level was presumably adopted. A between-subjects ANOVA performed on the scores for objective performance in Experiments 2 and 3 revealed a significant effect of SOA , $F(10,310) = 48.91$, $MSE = 47.13$, $p < .001$, $\eta_p^2 = .61$. Notably, neither the effect of Experiment ($F < 1$) nor the interaction effect, $F(10,310) = 1.32$, $MSE = 47.13$, $p > .2$, $\eta_p^2 = .04$, were significant. A similar ANOVA on the scores for subjective awareness revealed significant effects of SOA, $F(10,310) = 6.06$, $MSE = 70.97$, $p < .001$, $\eta_p^2 = .16$, Experiment, $F(1,31) = 5.74$, $MSE = 1518.12$, $p = .02$, $\eta_p^2\eta_p^2 = .16$, and SOA × Experiment interaction, $F(10,310) = 2.78$, $MSE = 70.97$, $p = .003$, $\eta_p^2 = .08$. A separate ANOVA performed on the scores for subjective awareness showed that the scores did not differ significantly across SOAs ($F < 1$).

These statistical analyses confirm the graphical evidence in Fig. 3a and b that the instruction manipulation in Experiment 3 resulted in a remarkable increment in overall scores for subjective awareness, without affecting the scores for objective

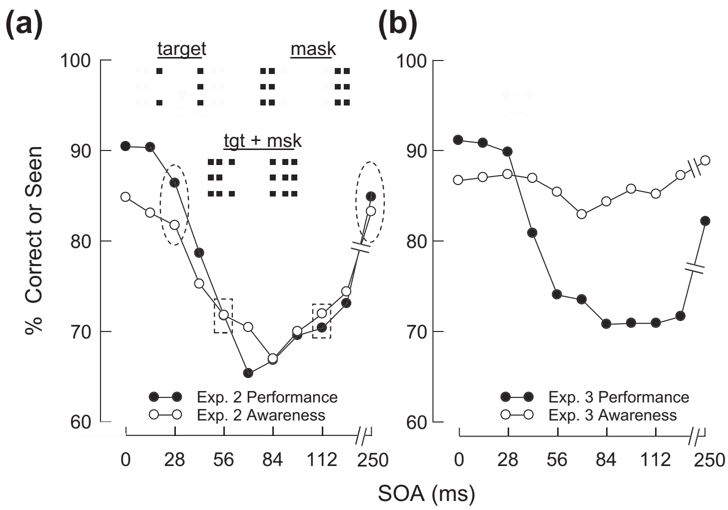

Fig. 3. (a) Results of Experiment 2 and (inset) diagrammatic representation of the stimuli. (b) Results of Experiment 3.

performance. Awareness scores did not increase uniformly across SOAs. Rather, the increment was most pronounced at intermediate SOAs. The reason for this selective effect of a change in criterion level is not immediately obvious. One possibility is that the estimates might have been constrained by a ceiling imposed by the 100% limit of the response scale. Obviously, this calls for further investigation. At any rate, the adoption of a more liberal criterion affected the measure of subjective awareness to such an extent as to make it impossible to carry out the type of comparisons required to assess relative blindsight as illustrated in the segmented shapes in Fig. 3a. This supports the conclusion that estimates of relative blindsight are affected not only by variations in criterion content but also by variations in criterion level. More generally, it is known that estimates of subjective awareness are affected by the specific measure used (e.g., Perceptual Awareness Scale, confidence ratings, or post-decision wagering; Overgaard, Rote, Mouridsen, & Ramsøy, 2006; Sandberg, Timmermans, Overgaard, & Cleeremans, 2010).

5. General discussion

The principal objective of the present work was to examine the phenomenon of relative blindsight using a metacontrast masking paradigm. In Experiment 1 we replicated Lau and Passingham's (2006) finding of an asymmetry in subjective awareness across two critical target-mask SOAs, given equality of objective performance. If that asymmetry is to be ascribed to relative blindsight, however, a key assumption must be met. Namely, that the criterion content is invariant across the two SOAs. That assumption was not met in Experiment 1 and in Lau and Passingham's experiment because the temporal integration of the stimuli employed in the two studies caused the criterion content to differ between the two SOAs. In Experiment 2 we used precisely the same paradigm (metacontrast masking) and very similar timing parameters as those used by Lau and Passingham. The important difference was that we used stimuli that were judged on the basis of a single criterion content, and found no evidence of the asymmetry obtained in Experiment 1. This led to the conclusion that the asymmetry reported by Lau and Passingham and confirmed in Experiment 1 arose not from relative blindsight but from different criterion contents at the two critical SOAs. Experiment 3 examined the effect of criterion level and illustrated the lability of judgments of subjective awareness as indices of relative blindsight.

Despite the evidence obtained in the present work, we believe that the notion of relative blindsight, as proposed by Lau and Passingham (2006), may be viable in principle. Namely, one can conceive of two conditions in which healthy observers exhibit the same level of objective performance but different levels of subjective awareness. Importantly, the main requirement for establishing the existence of relative blindsight is that a single criterion content be maintained throughout the performance of the perceptual task. The present study shows that that requirement was not met in Lau and Passingham's experiment. Indeed, the results of the present Experiment 2 question whether metacontrast masking is a suitable paradigm for establishing the existence of relative blindsight (for examples of employing metacontrast masking in studies of consciousness, see Del Cul, Baillet, & Dehaene, 2007; Haynes, Driver, & Rees, 2005; Van Aalderen-Smeets, Oostenveld, & Schwarzbach, 2006).

Based on the results of their behavioral study, Lau and Passingham (2006) conducted an fMRI study aimed at determining the neural correlates of relative blindsight. The results revealed a higher level of activity in dorsolateral prefrontal cortex (DLPFC) at the longer SOA. This was interpreted as reflecting a higher level of visual consciousness at the longer SOA, and as evidence of DLPFC involvement in relative blindsight at the shorter SOA. This instance of DLPFC activity, however, is open to alternative interpretations. Notably, it is known that DLPFC is involved in perceptual decision making (Heekeren, Marrett, & Ungerleider, 2008). This is consistent with the option, noted above, that the strength of the signal generated by the luminance-defined target at the longer SOA was greater than that of the signal generated by the target shape inferred from the four little triangles at the shorter SOA.

In a related study involving transcranial magnetic stimulation (TMS) over the cortical region identified by Lau and Passingham, Rounis, Maniscalco, Rothwell, Passingham, and Lau (2010) found that bilateral application of TMS to DLPFC impairs the observers' visual awareness without affecting objective performance. Because only one SOA (100 ms) was used in this study, the issue of different criterion contents did not arise. At any rate, this finding cannot be regarded as unambiguous evidence for relative blindsight because, as noted above, interference with processing in DLPFC might interfere not with conscious awareness *per se* but with perceptual decision making.[2]

5.1. Theoretical considerations

In his theory of conscious awareness, Lau (2007, 2010) has adopted a distinction between two types of neural representations: *First-order* and *higher-order*. First-order representations are those that arise from early sensory activity alone, independent of activity in higher cortical regions, notably prefrontal cortex. Higher-order representations, on the other hand, involve areas in prefrontal cortex, are *about* the first-order representations, and employ statistical information to enable judgments of perceptual certainty.

[2] Even if activity in a particular brain region is shown to be associated with metacognitive sensitivity (i.e. the efficacy with which subjective ratings of visibility distinguish between correct and incorrect responses), it does not necessarily follow that that brain region is critical for subjective awareness. Indeed, a recent study has shown evidence of sensory metacognition without conscious awareness (Kanai, Walsh, & Tseng, 2010).

Before using these concepts in the present context, a distinction needs to be made between the first-order representation of the *entire display* and the first-order representation of the *target*. The first-order representation of the entire display changed as the SOA was increased in all present experiments as well as in Lau and Passingham's (2006) experiment because the temporal integration of target and mask produced systematically different percepts. At short SOAs the percept consisted of the temporally-integrated target and mask (Fig. 1b, and tgt + msk sketch in the inset of Fig. 3a); at longer SOAs what was seen consisted of separate and sequential percepts of the target and the mask (Fig. 1c, and target and mask sketches in the inset of Fig. 3a).

This is not true, however, for the first-order representation of the *target*. In Experiment 2 the target was a luminance-defined image consisting of two columns of three dots each, with one dot missing (see inset of Fig. 3a). Notably, that image remained invariant across SOAs, regardless of temporal integration. Thus, the observers based their responses on the same stimulus attribute (the missing dot) at all SOAs. In this sense, the first-order representation of the target was invariant with SOA. In contrast, in Experiment 1 and in Lau and Passingham's experiment the first-order representation of the target varied as a function of SOA. Because of temporal integration, the image contained no luminance-defined target shape at short SOAs. Rather, the target's shape had to be inferred from the spatial arrangement of the four little triangles. This inference gave rise to a first-order representation that differed from the first-order representation based on the luminance-defined target at the longer SOAs. This is because temporal integration abates as the SOA is increased (Dixon & Di Lollo, 1994). In brief, the first-order representation of the target differed across SOAs in Experiment 1 and in Lau and Passingham's experiment but not in Experiment 2.

These considerations bear directly on the experimental evidence for the concept of relative blindsight. In proposing a higher-order theory of consciousness, Lau (2010, p. 4) has argued that "if one keeps the first-order representation constant, a change in the higher-order representations alone would be enough to change the character of a conscious experience." On this view, the asymmetry in subjective awareness obtained at the two critical SOAs in the present Experiment 1 and in Lau and Passingham's (2006) experiment, was due entirely to a change in the higher-order representation. A critical assumption in this conclusion is that the first-order representation of the target was the same at both SOAs. Here, we question the tenability of this assumption on the grounds – detailed above – that the stimuli in the present Experiment 1 and in Lau and Passingham's experiment gave rise to first-order representations that differed from one another across SOAs. Given the difference in first-order representations, the asymmetry in subjective awareness at the two critical SOAs cannot be attributed unambiguously to a change in the higher-order representation.

5.2. Concluding remarks

Unlike first-order views of consciousness (e.g., Block, 2007, 2009; Dretske, 1995; Lamme, 2006; Tse, Martinez-Conde, Schlegel, & Macknik, 2005; Zeki, 2003), higher-order views hold that subjective awareness is determined by higher-order representations whereas objective performance is governed by first-order representations (e.g., Armstrong, 1980; Kriegel, 2009; Lau, 2007, 2010; Lau & Rosenthal, 2011; Rosenthal, 2005, 2008). Thus, higher-order views are generally neutral regarding the utility of conscious awareness for task performance. For this reason, the finding in Experiment 2 that estimates of subjective awareness mostly co-varied with estimates of objective performance is not pertinent to higher-order theories. In contrast, this finding is consistent with the general views of Cohen and Dennett, 2011 who propose that, in principle, consciousness cannot be studied separately from function. This finding is also consistent with global neuronal workspace theory (GWT, Baars, 1998; Dehaene, 2008; Dehaene & Changeux, 2011; Dehaene & Naccache, 2001) in which conscious awareness is determined by activity in a network of neurons with long-range connections in prefrontal and parietal cortical regions. According to GWT, awareness-related activity in this network is positively related to the level of task performance. This view is buttressed by the results of Experiment 2 (Fig. 3a) which show that as the level of subjective awareness increases on either side of the trough of the function, so does the level of objective performance.

Acknowledgments

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