Chapter 3

# How can we measure awareness? An overview of current methods

Bert Timmermans and Axel Cleeremans



## Introduction

It would be pushing at an open door to state that the study of consciousness is challenging because it attempts to develop an epistemically objective approach to a phenomenon that is ontologically subjective (Searle 1997). How can I objectively have access to what another person thinks or experiences? Can a person him-/herself objectively assess or report what he/she thinks? Does introspection afford privileged access, or is it merely glorified heterophenomenology? And even if introspection were truly reliable, do introspective reports reflect one's actual phenomenological experience, or merely an interpretation thereof in light of task demands? These challenges, which present themselves in a particularly harsh light when it comes to establishing unconscious information processing, reflect the fact that the study of consciousness requires a solution to the following fundamental—and as yet unsolved—problem: *How can we measure consciousness?*

While there has been substantial progress in measuring the *level* of awareness (Casali et al. 2013; Sitt et al. 2014), and we have made steady progress delineating the neural correlates of consciousness (NCC) (Boly et al. 2013), we do not know of any instrument or method that makes it possible to measure the *contents* of awareness directly (Seth et al. 2008). Having such an instrument (i.e. a *consciousness-meter*) would make it possible to establish clear relationships between an external state of affairs, people's subjective experience of this state of affairs, and their overt behavior. However, neither does such an instrument exists nor can we conceive of any way of building it (though some are trying; Haynes and Rees 2005; Kamitani and Tong 2005; Formisano et al. 2008; Haynes 2009).

Thus, today, the best we can do to find out what someone currently experiences is to ask them to produce a report about it. Verbal report is the most *direct* method we can use to find out if a person is aware of some knowledge. But this, as appealing as it is, is fraught with complexity: people may refrain from or simply be unable to report on vague experiences; reports are typically not obtained at the time the experience occurs; people may be biased in different ways that often interact with each other (see Newell and Shanks, 2014, for a potent list of caveats). Even introspection—*first-person* data per excellence—has demonstrable limits (Nisbett and Wilson 1977; Johansson et al. 2006; Carruthers 2009). For these reasons, many authors have rejected *subjective* methods altogether and have

instead turned to using so-called *objective* methods. Objective methods typically involve asking people to choose between different carefully constructed alternatives (i.e. as in a two-alternative forced-choice task) rather than describing what they saw or felt. Objective methods, however, while they present the obvious advantage of producing *third-person*, objective data, make the debatable assumption that there is a clear distinction between *direct* and *indirect* appraisals of knowledge (see Figure 3.1).

Further, many authors have questioned the conceptual foundations of such methods for they presuppose, unlike subjective methods, that awareness of some information and (behavioral) sensitivity to that same information involve the very same processes. This approach, sometimes called the *objective threshold approach* or the *worldly discrimination theory approach* (Gaillard et al. 2006; Fu et al. 2008) takes it as a given that there is a perfect overlap between performance on a certain well-defined task and awareness. And yet, it is easy to imagine counter-examples. For instance, one can find oneself in a situation where one experiences a feeling of familiarity when seeing a word yet remains unable to ascertain with confidence whether one actually saw that word on a list sometime earlier. Is one's memory of that word *implicit* or *explicit?* Choosing a behavioral marker as being indicative of either of those processes requires making a priori assumptions about the relationships between observable behavior and consciousness, and there are but few empirical grounds to make such assumptions with reasonable confidence. For these and further reasons, recent years have seen an upsurge of interest in reinvented subjective measures, as well as wider adoption of *subjective threshold* approaches, through which one seeks to compare performance and self-reported awareness.

The above exposé is illustrative of how difficult it is to devise an appropriate measure of awareness. A further challenge is to devise appropriate *paradigms* through which to deploy such measures. Irrespective of whether the divide lies between subjective versus objective (subjective threshold) approaches or direct versus indirect (objective threshold)



| | **Objective** | **Subjective** | |
|---|---|---|---|
| | | **First-order** | **Metacognitive** |
| **Direct** | Identification<br>forced-choice<br>discrimination<br>Type I d' | Verbal report<br>PAS | Confidence judgment<br>wagering<br>Type II d' |
| | *Objective threshold* | *Subjective threshold* | |
| **Indirect** | Priming, RT | Behavioral or neural correlate of first-order experience | Behavioral or neural correlate of metacognitive judgment |

**Fig. 3.1** Relationship between different types of consciousness measures, indicating objective and subjective threshold.

approaches, most experimental paradigms dedicated to exploring the relationships between conscious and unconscious processing have relied on a simple *dissociation logic* aimed at comparing the sensitivity of two different measures to some relevant information: a measure *C* of subjects' awareness of the information, and a measure *P* of behavioral sensitivity to the same information in the context of some task. As discussed above, unconscious processing, according to the simple dissociation logic, is then demonstrated whenever *P* exhibits sensitivity to some information in the absence of correlated sensitivity in *C*. A typical example of such a situation is *priming,* in which processing a target stimulus is facilitated (*P*) by the prior presentation of an associated prime stimulus even when participants report (*C*) not having seen the prime.

There are several potential pitfalls with the simple dissociation logic, however. First, the measures *C* and *P* cannot typically be obtained concurrently. This *"retrospective assessment"* (Shanks and St John 1994) or *immediacy* (Newell and Shanks 2014) problem entails that finding that *C* fails to be sensitive to the relevant information need not necessarily imply that information was processed unconsciously during encoding, but that, for instance, it might have been forgotten before being elicited. A second issue is to ensure that the information revealed through *C* is indeed relevant to perform the task. This is known as the *information criterion* or *relevance criterion*. For instance, successful classification in an artificial grammar learning (Reber 1967; Cleeremans 1993) task need not necessarily be based on knowledge of the rules of the grammar, but can instead involve knowledge of the similarity relationships between training and test items. Participants asked about the rules of the grammar would then understandably fail to offer relevant explicit knowledge. A third issue is to ensure that *C* and *P* respect the *sensitivity criterion*, that is, that both be equally sensitive to the same relevant information.

Both the tension between objective and subjective methods and the relevance criterion problem suggest that it might simply prove elusive to hope to be able to obtain measures of awareness that are simultaneously *exclusive* and *exhaustive* with respect to knowledge held consciously. In other words, finding null sensitivity in *C*, as required by the dissociation paradigms for unconscious processing to be demonstrated, might simply be impossible because no such *absolute* (i.e. simultaneously exhaustive and exclusive) measure exists. A significant implication of this conclusion is that, at least with normal participants, it makes little sense to assume that conditions exist where awareness can simply be "turned off." Much of the ongoing debate about the existence of subliminal perception can be attributed to a failure to recognize the limitations of the dissociation logic, compounded by the inherent statistical limitations in reasoning based on null effects (for a discussion of how Bayesian approaches may help address this latter challenge see Dienes 2014).

It might therefore instead be more plausible to assume that any task is always sensitive to both conscious and unconscious influences (regardless of whether one conceives of conscious and unconscious influences as independent or not, which is a further issue). In other words, no task is *process-pure.* Two methodological approaches that specifically attempt to overcome the conceptual limitations of the dissociation logic have been developed. The first was introduced by Reingold and Merikle (1988), who suggested that

the search for absolute measures of awareness should simply be abandoned in favor of approaches that seek to compare the relative sensitivity of *direct* measures and *indirect* measures of some discrimination. The second approach—Jacoby's (1991) process dissociation procedure (PDP)—constitutes one of the most significant advances in the study of differences between implicit and explicit processing. It is based on the argument that, just as direct measures can be contaminated by unconscious influences, indirect measures can likewise be contaminated by conscious influences: particular tasks can simply not be identified with particular underlying processes (see also Dunn and Kirsner 1988). The PDP thus aims to tease apart the relative contributions of conscious and unconscious influences on performance.

With these considerations in mind, we first present a historical overview that may help explain how the current set of methods and measures came to be. We then proceed to analyzing different pending issues and attempt to offer ways forward.

## The quest for thresholds

In this section, we focus on what types of measurements we can seek to obtain with respect to consciousness. Somewhat paradoxically, the first measures of consciousness were not aimed at establishing conscious content, but rather at establishing the lack thereof. The main interest in developing a measure of awareness lay in trying to "peek behind the doors of the unconscious"—assessing the degree to which human behavior may be influenced by information that is not perceived consciously. Thus, the focus lay on establishing a threshold between conscious and unconscious processing, so taking consciousness as a dependent variable that may tell us something about whether and how the outside world was processed. The deceptively simple starting point was: can we, by varying stimulus intensity in one way or another, determine a point at which such a stimulus ceases or begins to be perceived?

### Subjective measures

#### Perception without subjective awareness

To understand the seemingly paradoxical importance of *un*conscious processing to the study of consciousness, one has to keep in mind that in the 19th century, whereas the existence of unconscious processes was acknowledged by both Hermann von Helmholtz and Wilhelm Wundt, it was believed that whether one could see a stimulus or not depended exclusively on stimulus properties, and that a weak stimulus simply failed to be picked up by the sensory organs. Peirce and Jastrow (1885) were the first to go against this notion and to empirically demonstrate *subliminal* visual perception, conceptualized as perception in the absence of conscious experience. They found that they could make accurate forced-choice judgments about the relative weight or brightness of objects, even when they reported no confidence in their own judgments. Similarly, Sidis (1898) showed people cards with a letter or digit from such a distance that participants reported not to be able to see anything, at which point he concluded that they were unaware of perceiving either digits

or letters. However, when he used a second measure—forced-choice guessing—his participants were able to guess the category of the card (digit or letter). Importantly, both Pierce and Jastrow's and Sidis' results do not merely show a dissociation between perception and awareness, with unconscious information influencing behavior; they also demonstrate that for one and the same stimulus one can design tasks that are differentially sensitive to aspects of perception related to consciousness.

Thus, while the *subjective*, verbal reports expressed by participants suggested that they had simply failed to entertain a visual experience of the critical stimuli, the *objective*, behavioral measures based on the forced-choice task suggested that they had nevertheless processed the stimuli to some extent. Crucially, the threshold delineating the boundary between conscious and unconscious perception is a *subjective threshold*: we say that participants are unaware of the stimulus when their report indicates no perception.

## Are subjective measures exhaustive?

Ideally, one would want any measure of any entity to be at least exhaustive, in the sense that you want it to capture any, even the most minimal, presence of that entity, all the more so if your goal is precisely to exclude that entity. This, of course, means that such minimal presence must be measurable in the first place. Indeed, a problem with the behavioral methods used by Pierce and Jastrow and Sidis is that their perception in the absence of awareness is crucially dependent on the notion that all mental states are at least potentially accessible to conscious report and that careful introspection can exclude the possibility that conscious knowledge bears on the objective measure (the forced-choice task).

However, failure to report knowledge may simply reflect a conservative *response criterion* (Eriksen 1956, 1960; Goldiamond 1958; Björkman et al. 1993). Thus, participants may fail to report knowledge not because they do not have it, but because it is held with very low confidence. According to Eriksen, rather than taking an awareness measure that is subject to such response bias, a better measure would be one that measures people's sensitivity rather than their response criterion. To put it simply, the core of the exhaustiveness problem tied to assessing absence of awareness is that *absence of evidence is never evidence of absence*: it is not because you fail to establish the presence of awareness that it is altogether absent (see section "Issues with measuring the absence and presence of awareness").

## Are subjective measures exclusive?

In addition to the requirement that measures of consciousness should be exhaustive (measuring *all* conscious knowledge), ideal measures of consciousness should also be exclusive: they should reflect *only* conscious knowledge. When a person reports his or her introspective awareness of a stimulus, then this rating will obviously be influenced by the degree to which he/she is aware of the stimulus, but it may also be influenced by *unconscious knowledge*. Indeed, if I assume that unconscious knowledge has a causal influence on a person's behavior, then there is every reason to think that this knowledge will also exert indirect influence on his/her introspection and reports. Assuming that the person was

shown a barely visible square and he/she reports having seen a square, then it is possible that this response is simultaneously informed by conscious and unconscious knowledge.

Another aspect of the exclusiveness issue was illustrated in a seminal study by Nisbett and Wilson (1977), who asked people to judge which of four pairs of nylon stockings they felt were best. People then had to justify their choice. Participants were unaware that the four items were in fact identical to each other and most actually chose the last pair they had examined. Nevertheless, most participants motivated their choice by appealing to the qualities of their chosen pair of stockings rather than simply stating that all pairs felt identical and that their choice had been arbitrary. This study, as well as later conceptual replications (Johansson et al. 2006), showed that people, even in the absence of relevant knowledge, will confabulate knowledge—knowledge that is perhaps influenced by unconscious processes. However, whereas people may indeed be poor at identifying the causes of their own behavior, this does not necessarily mean that their evaluation of their own phenomenal experience should automatically be disqualified. What such studies do point out is that people may not know what knowledge is enough for the correct decision. This *information criterion* issue implies that, even though participants may have seen a brief glimpse of a shape in a subliminal perception experiment, they will not report it, as they think it has no bearing on their response selection, where in fact it does. In other words, the conservative response criterion suggested by Eriksen may reflect not just people's unwillingness or inability to report what they see, but also the information criterion. Introspection depends not only on being able to report available information, but also on being able to identify task-relevant information.

The crisis of faith for introspective methods following Eriksen's critique had two major consequences: the move towards objective measures as a *direct* means of establishing the absence of awareness, and consequentially the use of priming and associated methods as an *indirect* way to show the influence of unconscious knowledge.



## Objective measures

### Objective measures and the introduction of priming

According to Eriksen, subjective reports might reflect a participant's response criterion (indicated as *c* in the formalism of signal detection theory (SDT), see Green and Swets 1966; Macmillan and Creelman 1991) to one specific conscious process, rather than being indicative of the boundary between conscious and unconscious experience. Discriminability, or sensitivity, on the other hand (indicated by *d'*), is held to be independent of such a bias according to SDT. Subsequently, forced-choice identification tasks have come to be known as "objective measures of awareness": if a person can discriminate between two stimuli, then he/she must have been aware of them. Obviously, this very definition makes subliminal perception a priori impossible, since the phenomenon is understood as visual abilities (e.g. discrimination) in the absence of consciousness. Were consciousness to be operationalized as one such "visual ability," clearly, one could never find "visual ability in the absence of consciousness."

What was therefore needed was a different paradigm that could show presence of knowledge in the absence of ability to discriminate (identify, recognize). Thus, instead of contrasting *subjective* and *objective* tasks to dissociate awareness and performance, as the earliest studies had done, the focus now shifted towards contrasting comparable *direct* and *indirect* tasks, whereby the direct measure should yield null sensitivity. Unconscious processing is then demonstrated through the *indirect* influence it exerts on subsequent processing. Thus, in priming studies, a stimulus (prime) that is presented below the objective threshold is shown to have an influence on processing of a subsequent (target) stimulus.

In the early 1980s, Marcel (1980, 1983) used masking to render a word invisible, and measured how this masked word (the prime) facilitated detection of a subsequently presented word (the target) when the two words were semantically related. For instance, the masked presentation of "table" facilitates detection of "chair." Such semantic priming was later replicated with words (Fowler et al. 1981; Balota 1983), but also with pictures (McCauley et al. 1980; Carr et al. 1982). Until the mid-1980s, priming was the paradigm of choice for the study of unconscious influences on behavior (for an overview of semantic priming, see Van den Bussche et al. 2009) and objective measures would become the "gold standard" for excluding awareness. While priming research would later be criticised with respect to the method of masking the stimulus (Holender 1986; see section "Degraded, rather than unconscious perception"), we will first list a number of problems with objective measures.



## Are objective measures exclusive and exhaustive?

Above-chance performance on a forced-choice task involving the masked stimulus need not necessarily be due to conscious knowledge. In other words, objective measures may well be exhaustive, but they cannot be taken to be exclusive, as zero discriminability may in fact rule out any unconscious perception or knowledge as well, making it impossible to be certain of what is in fact being measured, if anything at all (Dixon 1971; 1981; Jacoby et al. 1992; Merikle and Daneman 1998). Nonetheless, exhaustiveness remains an issue: although the objective test is very strict, determining that $d' = 0$ is equivalent to testing a null hypothesis, meaning that you need very strong statistical power to be able to maximally reduce the probability of type 2 error. Again, one cannot escape the simple notion that absence of evidence is not evidence of absence. Many studies reporting under-chance discrimination (Balota 1983; Marcel 1983) have not demonstrated a total lack of conscious experience, and the issues with objective tasks and sensitivity have recently been confirmed (Lin and Murray 2014).

## Are objective measures robust?

Objective measures are considered the gold standard because they are supposed to be essentially strategy- and bias-free, and hence very robust. However, they may not be as robust as they seem. Vermeiren and Cleeremans (2012), using a metacontrast masked forced-choice task, showed an influence of different variations of the *d'* task on the resulting *d'* values. Dividing attention over the prime and target decreased *d'* values, suggesting that *d'* values are overestimated when using the standard *d'* task because participants are

not required to pay attention to the primes during the priming blocks. Still, participants were impaired in detecting the primes with valenced targets because they tended to report the direction of the targets instead of the direction of the primes. This results in an underestimation of *d'* in the standard *d'* task, since failure to inhibit targets does not imply that the primes were not visible at the moment they were presented. Because this underestimation effect was larger than the overestimation effect, we can conclude that, in general, *d'* values are underestimated using standard *d'* tasks. Furthermore, higher *d'* values were observed when participants had to wait before responding. Thus, apart from suggesting that *d'* isn't the robust measure it has been made out to be, what these findings show is that the *d'* task on the primes suggests a phenomenology that was never associated with the primes as they occurred during the experiment in the first place.

## Criticism of the stimulus, and proposals to use awareness as the independent variable

### Degraded, rather than unconscious perception

In 1986, Holender published his seminal paper, essentially demonstrating that the vast majority of studies claiming subliminal priming could not, in fact, exclude the possibility that the stimulus had been minimally or partially conscious, and suggested that the reported dissociations between consciousness and performance were probably due to degraded, rather than truly unconscious perception. This led to a number of critical evaluations of the semantic priming effects as shown by Marcel (1983). Most importantly, by establishing an individual threshold at the outset of the experiment, participants' conscious experience of masked primes during the experiment was greatly underestimated, and subsequent experiments showed priming effects to be correlated with prime visibility (Nolan and Caramazza 1982; Purcell et al. 1983). Thus, prime visibility should be established at least after the experiment, rather than before. Furthermore, through a process called *retroactive priming*, primes could be retroactively rendered more visible by the target word. Some of the methods that are commonly used to try to achieve prime invisibility are listed in Box 3.1.



### Box 3.1 Perceptual awareness: methods to render a stimulus invisible

Since the 1980s, a number of different methods have been put forward to render a stimulus invisible, as detected by subjective or objective methods, respectively. Going into each of them in detail is beyond the scope of this chapter. Below we briefly describe the most important ones, ranked from methods whereby stimulus intensity or visibility is manipulated in order to get different levels of awareness, to methods where the stimulus is usually kept constant and the conscious percept changes (see also Frith et al. 1999, for an overview, also of methods beyond perceptual awareness).

**Box 3.1 Perceptual awareness: methods to render a stimulus invisible** *(continued)*

- **Visual masking (forward/backward/metacontrast)**. Masking paradigms are perhaps the most widely used and best known of all methods. In all variants, a stimulus (the prime) is rendered invisible by presenting another stimulus (mask, sometimes also the target) either simultaneously or before (forward) or after (backward) the prime. The goal is to avoid an after-image, which would make the stimulus present in the visual system for longer than it was actually presented. Metacontrast masking is different in nature in that it involves "covering" a stimulus with the negative not just of that stimulus, but of all stimuli in a set.
- **Attentional blink**. This paradigm relies on a limitation of the attentional system, whereby people are required to identify a specific stimulus in a rapidly presented series of stimuli. When they see this stimulus, it causes a second stimulus presented briefly thereafter in the series to go by unnoticed.
- **Visual crowding**. This paradigm induces invisibility by surrounding a peripherally presented stimulus with unrelated stimuli, possibly combined with an eye-movement feedback that keeps the stimulus in the peripheral field when the eyes move.
- **Continuous flash suppression**. In this paradigm, one eye is presented with a stimulus, while the other is presented with a continuously flashing pattern. Because of this, the stimulus can be kept out of conscious perception for a considerable time, after which it starts to appear (*breakthrough*).
- **Perceptual fading and motion-induced blindness**. In these paradigms, based on an inherent property of the visual system, one or more features of the image gradually disappear from conscious perception as the person is looking at it. With perceptual fading, people often have to focus on a specific spot, causing the rest of the image to gradually disappear. With motion-induced blindness, a stationary part of a stimulus disappears from the conscious percept through the movement of a different stimulus that overlays the former. In both cases, the effect is easily undone by eye movement.
- **Reversible figures and binocular rivalry**. In both paradigms, the conscious percept is not present or absent, but instead switches, either spontaneously or deliberately, between two images independently of a stimulus held constant. In the case of a reversible figure, the switch occurs because the stimulus can be seen as either of two possible percepts that are physically mutually incompatible, or constitute a switch in figure/ground perception. In the case of binocular rivalry, each eye is presented with a different stimulus, such that they cannot be fused into one percept, which causes the conscious percept to "switch between eyes."

### The strength–efficacy dilemma

The strength–efficacy dilemma refers to the fact that a significant challenge in the study of the differences between conscious and unconscious process consists in determining the point, on a performance continuum, where processing can confidently be characterized as involving unconscious processing. Typically, this is obtained by varying the strength of the stimulus in such a way that behavior falls somewhere between the objective and subjective thresholds. On the one hand, degrading the stimulus too much incurs the risk of failing to obtain detectable behavioral effects (e.g. an absence of priming). On the other hand, strengthening the stimulus too much incurs the risk that participants become aware of it (as awareness cannot be turned "off"). Finding the precise point at which the stimulus is strong enough to exert a detectable influence on behavior yet not so strong that participants become aware of it is a formidable challenge in most relevant experimental situations, particularly when low power and statistical issues are also taken into account.

### Contrastive analysis: awareness as an independent variable

In 1989, Baars proposed yet another solution, which would prove fruitful in future neurobiological studies. Baars reasoned that if in manipulating the stimulus, via masking or duration, one tampers with its processing irrespective of awareness, then perhaps the best way to look at the difference consciousness makes is to keep experimental conditions as similar as possible between conscious and unconscious trials and to manipulate consciousness as an independent variable. Obviously, this also holds for conditions around threshold, in that there never really is a cut-off at which all trials are either conscious or unconscious. There are, however, a number of properties inherent to the attentional and visual system that can make a stimulus invisible in the absence of any physical stimulus change (see Box 3.1). Thus, rather than creating stimulus-based conditions in which one measures performance and awareness, one should aim to create situations where one can classify the trials as being conscious or unconscious, and then look at resulting performance, or its neural correlates (Rees 2007; Tononi and Koch 2008; Koivisto and Revonsuo 2010; Dehaene and Changeux 2011).

However, logical as this approach may seem, there are again a number of pitfalls. First, contrasting trials with and without conscious perception of a target, rather than corresponding exclusively to the phenomenology of awareness (the NCC), may also reflect processes that precede or follow conscious perception—its causes and consequences (Pins and Ffytche 2003; Del Cul et al. 2007; Melloni et al. 2007; Aru and Bachmann 2009a, b; Gaillard et al. 2009). Second, the contrastive approach, which is rooted in Global Workspace Theory (Baars 1989), assumes that it is by virtue of a stimulus becoming conscious, i.e. entering into global workspace, that it becomes available to all sorts of processes qualitatively different from those associated with unconscious stimuli. However, Lau and Passingham (2006) showed that the same awareness level can be associated with different levels of performance. Indeed, while both the dissociation logic and the contrastive approach may surmise that differences in awareness lead to differences in processing, they say nothing about whether lack of difference in awareness indicates comparable processing.

The main problem, however, is that the contrastive approach fails to avoid the general issues associated with dissociative logic, in that it still requires a measure, objective or subjective, that unequivocally classifies a stimulus as conscious or not.

## Beyond dissociation logic and thresholds

From the mid-1980s onwards, the idea of a clear dissociation between conscious and unconscious processes, and the plausibility of measuring it, began to be replaced by more nuanced proposals. There were amendments to the existing threshold models: Greenwald and colleagues (Greenwald et al. 1996; Draine and Greenwald 1998) proposed the existence of an additional threshold in their objective threshold/rapid decay model, in that they assume that objective threshold effects are real, but very short lived, whereas subjective threshold effects, as reported by Merikle (1984; see also 1992) are probably weak conscious effects, which participants fail to report. Even more recently, Snodgrass and colleagues (2004a, b) proposed a third, objective threshold/strategic model which, while it also assumes that objective threshold effects are genuine, further adopts a dual process view of perception. In their view, every process has relatively independent conscious and unconscious components. As a consequence, not only do conscious effects gradually become stronger with increased stimulus intensity, but also unconscious effects become weaker as these conscious effects override them.

### No task is process-pure, hence no measure can be

Already in 1971, Dixon suggested that conscious and unconscious perception allowed for qualitatively different processes. This was expanding on the subjective/objective task dichotomies, in that, rather than looking at awareness and task performance in terms of presence or absence, it surmised that if awareness of a particular stimulus differed, then this should lead to qualitatively different performance. Later, Cheesman and Merikle (1984, 1986) would turn this around and argue that the existence of such qualitatively different processes in two conditions of different stimulus visibility is enough to support the idea of a (subjective) threshold between them. Indeed, Marcel (1980) presented people with context/prime/target words that could be either congruent (hand/palm/wrist) or incongruent (tree/palm/wrist), and showed that when the prime was invisible, there was facilitation in both conditions, but when the prime was visible, there was both facilitation for congruent trials and interference for incongruent ones.

Rather than interpreting this in terms of absolute absence or presence of awareness, Reingold and Merikle (1988) suggested that the search for absolute measures of awareness should simply be abandoned in favor of approaches that seek to compare the sensitivity of *direct* measures and *indirect* measures of some discrimination. Direct measures involve tasks in which the instructions make explicit reference to the relevant discrimination, and include objective measures such as recognition and recall. In contrast, indirect measures, such as stem completion in implicit memory tasks, make no reference to the relevant discrimination. By assumption, direct measures should exhibit greater or equal sensitivity

than indirect measures to consciously held task-relevant information, for participants should be expected to be more successful in using conscious information when instructed to do so than when not. Hence, demonstrating that an indirect task is more sensitive to some information than a comparable direct task can only be interpreted as indicating unconscious influences on performance (see Jiménez et al. 1996, for an illustration of application to sequence learning).

### Process dissociation

Debner and Jacoby (1994) took the above idea one step further by proposing that one such qualitative difference between conscious and unconscious perception or knowledge was the degree to which one had control over it. Their process dissociation procedure (PDP) appeals to contrasting "inclusion" and "exclusion" conditions: in inclusion conditions, participants are to report the stimulus they have just seen, whereas under exclusion conditions, participant are asked to avoid reporting what was seen. Under inclusion instructions, conscious and unconscious processes work in unison and both contribute to increasing performance. However, in exclusion, any unconscious knowledge works *against explicit task instructions*. Thus, items that are reported despite explicit instructions not to do so have to constitute knowledge that was not under conscious control. Debner and Jacoby showed that when people performed a stem-completion task after memorizing a word list, some words were only completed in the inclusion condition (explicit memory), while some were also (or only) present in the exclusion condition (implicit memory). Indeed, using this procedure it is in principle possible to show the presence of unconscious knowledge, something that, using subjective methods, is always confounded with potential lack of exhaustiveness (see Destrebecqz and Cleeremans 2001, for an application to sequence learning). However, even the exhaustiveness of PDP has recently been questioned, in that knowledge that showed up in the exclusion task (and is hence supposed to be unconscious) was reported in subjective tests as being very weakly conscious, suggesting that the criterion for reporting awareness is more liberal than for exclusion (Sandberg et al. 2014).



## Renewed focus on the subjective threshold

Whereas the shift from a threshold-based logic to the idea of relative contributions of conscious and unconscious processes has made an excellent contribution to the empirical problem of measuring consciousness, it has moved the field away from subjective phenomenology. Crucially, these approaches tacitly assume that researchers can devise tasks that allow them to decide what participants saw with more authority than those participants themselves, whereas the issue at stake is simply: What does a person experience and how does he/she experience it?

One of the phenomena that has rekindled interest in subjective measures is *blindsight*, a condition in which radically different levels of awareness correspond to roughly similar performance. Blindsight refers to the impressive discovery that at least some patients with lesions to the primary visual cortex exhibit preserved visual functions such as perception of movement direction (Weiskrantz et al. 1995), target detection (Pöppel et al. 1973), and spatial summation (Leh et al. 2006), even though they report to be fully blind in a part of the

visual field corresponding to the location of the injury (but see Overgaard et al. 2008, who suggest that blindsight is merely severely degraded processing). As such, blindsight should be considered "less interesting" than subliminal perception in healthy subjects, as the phenomenon has so far only been studied in a few patients. However, in those patients, blindsight has proven to be so consistent and persuasive as an example of an almost unbelievable discrepancy between subjective report and behavioral reactions (such as the ability to discriminate) that many researchers see it as the primary source of evidence for subliminal processing.

What we learn from blindsight is that the attempt to "replace" subjective methods in any direct sense with objective methods is in itself a very problematic enterprise. Arguing, say, that some objective method like forced-choice discrimination lends a "more direct" insight into the contents of consciousness rests upon circularity (Overgaard 2006). There may be fixed contingent relations between certain responses and experience, so that the existence of the former gives us right to claim that a subject has a certain experience. However, finding the correct objective measures is impossible without making use of subjective data, e.g. an introspective report. That is, associating a certain report such as a correct identification with consciousness is only possible with empirical evidence, i.e. a correlation between the response and the relevant conscious state. Since the conscious state cannot in itself be observed from the outside, the use of an introspective report about the relevant state seems to be the only possible methodology. Accordingly, no other kind of response can be a more reliable indication of a given conscious state than introspective report. This conclusion logically follows from the fact that the response is associated with the conscious state only by way of its correlation with the introspective report. Therefore, subliminal perception must be studied with complementary methods, and no real conclusions regarding the nature or the very existence of unconscious processes can be made without some measure based on introspection. Box 3.2 lists several of the currently available subjective measures of awareness (see also Overgaard and Sandberg 2012; Zehetleitner and Rausch 2013).



## Box 3.2 Subjective measures

Below we briefly describe a number of commonly used subjective awareness measures and their advantages and disadvantages. Failure for a method to be exhaustive can be related either to a lack of incentive for participants to reveal all knowledge, or to the fact that people may simply not know which information is potentially relevant to the behavioral task (the information criterion). Failure for a method to be exclusive may relate to either the test reflecting information below a level we are interested in, or the fact that unconscious influences may boost the subjective rating, as it is in principle also a behavioral measure.

- ***Perceptual awareness scale (PAS)*** (Ramsøy and Overgaard 2004)—people rate whether they have seen nothing, a "brief glimpse" of something, an "almost clear" stimulus, or a "clear stimulus." Critically, the scale was originally developed by having people freely rate their awareness, from which a natural four-point scale emerged. PAS potentially has incentive-related exhaustiveness issues in that

**Box 3.2 Subjective measures** *(continued)*

people have no incentive to reveal knowledge. It has no information criterion-related exhaustiveness issues, since it is not judgment related and people need not know how what they saw relates to their judgment. It has potential exclusiveness issues in that the "brief glimpse" point may reflect "awareness" below the level one is interested in. A similar ***continuous visual analog scale*** (Sergent and Dehaene 2004), asking participants to place a cursor on a line with two labels, "not seen" to "maximally visible," in principle shares the same characteristics, but as people seem to use this scale more dichotomously, either exhaustiveness issues or exclusiveness issues may be more important. For use in implicit learning paradigms, PAS has been modified as the ***rule awareness scale*** (Wierzchoń et al. 2012)—however, by asking people explicitly how aware they are about the rules of an artificial grammar, you explicitly probe the task-related knowledge that PAS seeks to avoid.

- ***Confidence ratings (CR)*** (Cheesman and Merikle 1986; Dienes et al. 1995)—these have been used in many guises, from 51-point scales to just "guess" vs "know," and are still one of the most widely used methods. CR have the same potential exhaustiveness issue as PAS and in principle no information criterion-related exhaustiveness issues: they were designed to avoid people having to introspect. Nonetheless, people may fail to report confidence if they possess partial knowledge that they cannot causally relate to the task, because in the most commonly used version they need to express confidence in their performance, not in what they saw. The fact that people need not introspect may lead to exclusiveness issues in that a confident "gut feeling" may reflect unconscious and not conscious influences.
- ***Post-decision wagering (PDW)*** (Ruffman et al. 2001; Persaud et al. 2007)—this method is essentially aimed at eliminating the incentive-related exhaustiveness issues of PAS and CR, by having people wager money on their response. Hence, it has supposedly no exhaustiveness issues, at least when one uses no-loss gambling. Otherwise the risk of losing money will actually decrease exhaustiveness. Like CR, it has in principle no exhaustiveness issues based on the information criterion, even though in practice people may link their rating too much to the task, as they also have to wager on their performance. Likewise, it could be that a "gut feeling" for a high wager reflects unconscious influences.
- ***Feeling of warmth*** (Metcalfe 1986)—this is comparable to CR, except that rather than referring to people's confidence in their judgment, it asks people to rate their feeling of warmth about what they saw. This makes it slightly more intuitive than CR, and hence it has even fewer issues with exhaustivity, since it asks for neither knowledge nor judgment. It shares the incentive exhaustiveness issue with PAS/CR, even if slightly less so, as people have to relate their response even less to their decision. It may have more exclusiveness issues as it relies on a "gut feeling" which, as for CR, may reflect unconscious influences.

## Issues with measuring the absence and presence of awareness

At the outset of this chapter, we argued that the central problem faced by consciousness research is that we do not have a *consciousness meter*. In other words, we can only infer consciousness from observable behavior. Whereas in the historical overview we briefly touched upon the different methodological pitfalls that this entails, here our aim is to look at the consequences of the fact that we can only access consciousness through measurable behavior. Thus, we first look at the problems inherent to measurement, and subsequently at the problems linked to using behavior as a marker.

### The observer paradox: confounding awareness and report

The observer paradox simply refers to the fact that asking people to produce subjective reports or to reflect in any way on their own performance may change the very processes that are being monitored.

Thus, it may be that that content is actually obscured by the processes involved in reporting. In a recent study, Frässle et al. (2014) had participants perform a binocular rivalry experiment, asking them to report their perception continuously. They found that optokinetic nystagmus and pupil size matched people's reports, so that indexing both makes it possible to determine people's subjective experience of the stimulus without asking them to produce a report. Thus, using optokinetic nystagmus and pupil size to objectively and continuously map perceptual alternations, they were able to compare a report condition with a passive condition in which no active subjective report was requested from participants. They found that only in the active report condition functional magnetic resonance imagery (fMRI) findings matched those of earlier studies that associate binocular rivalry with activity in occipital, parietal, and frontal areas. In the passive, non-report condition, neural activity in the frontal area was completely absent. Hence, subjective measures have the problem that they require additional processing that does not in and of itself have anything to do with conscious experience.

This finding has important conceptual consequences in the search for the neural correlates of consciousness (NCC). It strikingly illustrates that the observer paradox is at play in most contemporary paradigms designed to explore the differences between conscious and unconscious processing. Importantly, this caveat applies to not only studies of perceptual experience, but also any task in which participants are asked to carry out some form of introspection about their own mental states. One way to avoid the observer paradox altogether consists of abandoning subjective measures in favor of objectives measures.

Furthermore, Block's distinction between access consciousness and phenomenal consciousness (Block 2007, 2014) is also connected to this point (as well as to exhaustiveness issues in general), and forms the basis for the *overflow argument*: the idea that phenomenology is always richer than what we are able to report about it. Conversely, it has been argued (Kouider et al. 2010) that rather than being the result of a rapidly decaying phenomenology, consciousness is essentially constructive. It takes at least some time to build a conscious representation of the world, and this representation is shaped by not only the

stimulus but also our priors. What both points of view hold in common is that the moment at which you measure awareness is not necessarily reflective of content that was conscious at the moment of perception. Indeed, whether one measures awareness before or after performance on an objective task may influence reported awareness (Wierzchoń et al. 2014).

## The performance paradox: confounding awareness and performance

Whereas we might assume that awareness will increase performance, assuming any a priori relationships between awareness and performance precludes finding any unexpected dissociations. This becomes all the more clear when trying to define awareness in terms of how people's awareness ratings correlate with their performance—something that subjective threshold approaches have been reflecting in a number of ways.

### Disentangling bias and sensitivity in subjective measures

As mentioned in the section "Are subjective measures exhaustive?", Eriksen (1960) criticised subjective methods for not being able to dissociate response bias from sensitivity. In an attempt to overcome this limitation, inspired by theoretical assumptions that either consciousness results from the brain reflecting on itself (higher order thought; Rosenthal 1997, 2006) or that such a process is consequential to and indicative of consciousness ("fame in the brain" theories; Dennet 1991, 2001; Dehaene et al. 1998), it has been suggested that if there is a systematic way in which awareness scores are related to performance, this is indicative of conscious knowledge. There are two roughly comparable approaches to this: meta-*d'* on the one hand, and the zero correlation criterion (ZCC) and guessing criterion (GC) on the other hand.

**Meta-*d'*** Meta-*d'* (sometimes referred to as *d*") is the application of signal detection theory (SDT) to awareness ratings: where *d'* represents the sensitivity of a system to states of the outside world, meta-*d'* represents the sensitivity of a system to its own internal states (Galvin et al. 2003; Maniscalco and Lau 2012, 2014). If I am able to discriminate between stimulus and noise, or two stimuli, my *d'* is high. In objective threshold models, this means that I am conscious of the stimulus. In subjective threshold models, however, $d' > 0$ can occur with or without awareness. Thus, as a rule, it is assumed that if I know when I have made such a correct discrimination and when not, my meta-*d'* will be high. Thus, if any two awareness ratings differ between average number of correct and wrong answers they are associated with, there is some consciousness, or, more precisely, some proportion of trials probably was accompanied by consciousness. It is perhaps easier to illustrate this principle though the ZCC and GC approach.

**Zero correlation and guessing criteria** In 1995, Dienes and colleagues introduced two criteria to assess whether performance was influenced by knowledge that was above the objective threshold, but below the subjective one: the GC and the ZCC (Dienes et al. 1995). The former assesses how performance behaves in the absence of reported awareness, the latter the degree to which performance and awareness are related.

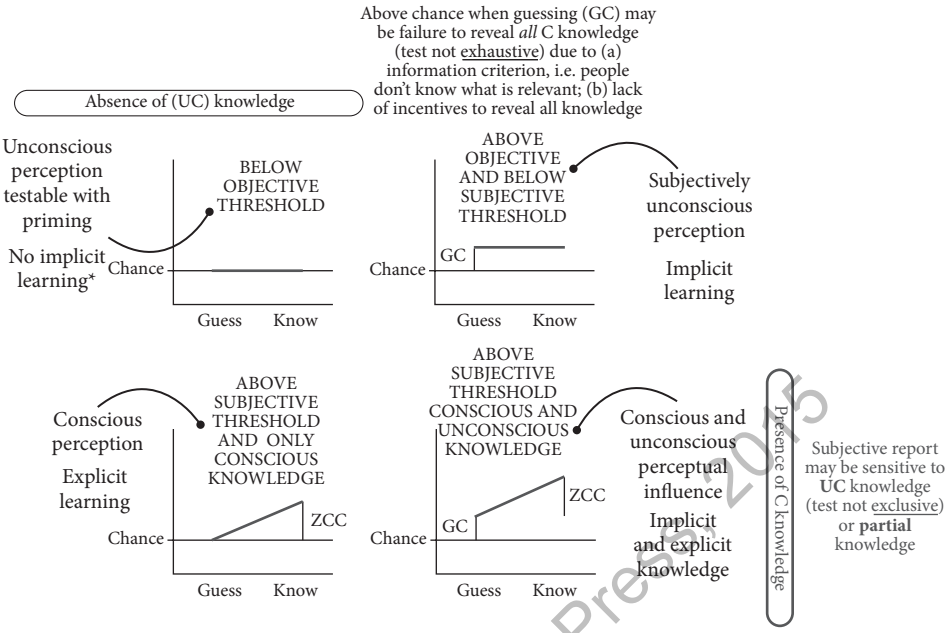


**Fig. 3.2** The pitfalls of using behavior as a marker for consciousness. Illustration of the use of the Guessing Criterion (GC) and Zero Correlation Criterion (ZCC), showing that they allow one to assess the absence of knowledge or the presence of conscious (C) knowledge, but in principle not the presence of unconscious (UC) knowledge.



Dienes and colleagues write that a strong indication for the existence of unconscious knowledge is—much like with meta-*d'*—when there is no systematic relationship between performance and awareness scores (ZCC), or, additionally, when you observe above-chance performance when people claim to be guessing or give the lowest awareness rating (GC). This gives rise to four possible performance/awareness patterns, as depicted in Figure 3.2[1], for ZCC and GC, but which in principle hold for any measure that tries to bypass Eriksen's critique by defining awareness in terms of its relationship with performance. Knowledge can be:

- Below the objective threshold: no directly measurable knowledge (top left). When people perform at chance on trials where they claim to be guessing as well as trials where they claim to know, knowledge either is absent or falls beneath the objective threshold.

[1] A potential fifth pattern is the one observed by Scott et al. (2014), in which participants have some meta-knowledge without actually performing above chance. This could be visualized by a line with an upward slope, the ends of which lie below and above chance performance for guessing and knowing, respectively. What happens in this case is that on average people perform at chance, let's say 50 trials correct and 50 trials wrong. However, for the 50 correct trials they rate their awareness higher than for the 50 wrong trials. This effectively means that people may be able to evaluate their own performance on each trial, without necessarily having overall above-chance performance. This also illustrates a problem with averaging performance across many trials, because obviously on any given trial when there is enough signal to get an increased awareness rating, you also have a higher chance of being correct.

This is usually the criterion used when assessing unconscious perception of the prime in priming studies. In implicit learning studies, there would simply be no measurable knowledge.

- Above the objective but below the subjective threshold: unconscious knowledge (top right). When people perform above chance when they claim to guess, and there is no difference in performance between trials on which they claim to guess or know, both the GC and the ZCC have been satisfied, and we can assume that knowledge is subjectively unconscious. Whereas in priming studies the conclusion would be that the prime was visible, this is typically the patterns found in implicit learning studies.
- Above the subjective threshold, with only conscious knowledge (bottom left). Here, neither the GC nor the ZCC have been satisfied: there is no above-chance performance when participants claim to be guessing, only when they claim to know. This pattern would mean that any knowledge is conscious, so fully conscious perception and explicit learning is implied.
- Above subjective threshold, with both conscious and unconscious knowledge (bottom right). Here the GC is satisfied, but not the ZCC. This implies the more realistic situation in which both conscious and unconscious knowledge contribute to task performance.

One obvious flaw in the ZCC and GC approach is that while chance performance when guessing shows absence of knowledge, and while a correlation between performance and awareness scores might show presence of conscious knowledge (see next section for a critique), no pattern shows presence of unconscious knowledge. Indeed, above-chance performance when guessing or an absence of correlation can always be the result of the test failing to be exhaustive, or of people using the wrong information criterion. Furthermore, an observed correlation can also stem from a non-exclusive awareness test, where ratings are partially the result of unconscious knowledge. An additional obvious problem is that, in using the ZCC/GC or meta-*d*', one abandons the ability to establish, for any single stimulus, whether it was consciously perceived or not, simply because computing correlations requires many trials.



## Confounding awareness and performance is confounding awareness and metacognition

Despite the usefulness of the above measures, they share one problem: they are not truly assessing the presence of unconscious knowledge—they presuppose its existence. What the ZCC/GC approach and meta-*d*' share is that they make "awareness" dependent on how people's subjective ratings of their awareness correspond to their accuracy on the behavioral task. This means that, for instance, if you want to show a dissociation between awareness and performance, then, for a certain performance level, you should not show that you have two situations in which you have different awareness ratings (which would represent only a shift in criterion), but rather that these awareness ratings correlate differently with said performance.

One potential issue with measures relating awareness to accuracy is that it measures metacognitive acuity rather than awareness, and any conclusion on awareness rests on the *assumption that measuring metacognitive acuity is an exhaustive and exclusive indicator of awareness*. Perhaps it isn't either of those, and there is a conscious phenomenology that does not contribute to metacognitive acuity, so metacognitive acuity may be too strict a criterion. More importantly, however, the notion of metacognitive acuity may be too lenient and not be exclusive: following the classic adage that correlation is not causation, one could easily imagine information that is not consciously perceived having an influence on *both* accuracy and awareness ratings in an unconscious way. So you could get highly correlated awareness and accuracy measures, and *still* not have a demonstration of awareness.

## Implications

### A measure is only exhaustive relative to other measures

Our argument that a measure is only exhaustive relative to other measures is not stating that subjective tests cannot be used—instead, we make the claim that they should be used with caution and only relative to other scales. Since ZCC and GC cannot in principle demonstrate unconscious knowledge that is due to the test's failure to be exhaustive, this implies that for any given task the best awareness test is the one that shows the least unconscious knowledge and the most conscious knowledge. This may seem counterintuitive, but the idea is quite simple: assume that for a certain stimulus, one awareness test indicates no correlation with performance, but instead above-chance performance when participants claim to be guessing—both indicating unconscious knowledge. If we can find an awareness test that, for the exact same stimulus, shows a correlation with performance and chance performance when guessing, then this means the first test simply failed to be exhaustive. Studies that compared subjective tests of awareness have suggested that for perceptual awareness, PAS is the most exhaustive, with CR performing only slightly worse (see Box 3.2; Sandberg et al. 2010, 2013; Szczepanowski et al. 2013; Wierzchoń et al. 2014). When probing conscious knowledge in an implicit learning task, CR has been shown to be the most exhaustive and sensitive test (Wierzchoń et al. 2012).

### Exclusiveness and the inability to escape the criterion content issue

The above issue begs the question: what do we measure and what do we want to measure? In the Sandberg et al. (2010) experiment, PAS was shown to be more exhaustive than CR or PDW, in that PAS showed a correlation between accuracy and awareness at very brief stimulus durations, whereas CR and PDW showed no such correlation and instead suggested above-chance performance at zero awareness, illustrating that PAS somehow captures more of people's awareness of the stimulus. Dienes and Seth (2010) commented that since PAS has a scale point labeled "brief glimpse," which is not referring to any stimulus identification, what was perhaps measured was not relevant conscious content, but merely the existence of a fleeting unspecific conscious experience. They argued that such "brief glimpse" content may not constitute knowledge that participants can consciously relate to the judgment, and that such contents should therefore instead be considered

unconscious knowledge. In other words, PAS simply fails to be exclusive. In a reply, Timmermans et al. (2010) argued that this may be because PAS "brief glimpse" scores, while not requiring specific task-related content to be identified, may reflect information that has enough diagnosticity at a behavioral level, but not at a phenomenological level. In other words, participants' PAS ratings, because they do not refer to judgment knowledge related to the response alternatives of the task, may be more sensitive than other measures to *any* consciously perceived information, including information which, while not sufficient to produce conscious identification, may nevertheless result in improved behavioral performance. Thus, criterion content could play much less of a role with PAS than with CR because CR, depite being intuitive, nevertheless depends on what participants think is relevant to the task at hand.

Interestingly, using an artificial grammar learning task, Wierzchoń et al. (2012) showed that the CR scale is the most exhaustive and most sensitive for an implicit learning task. However, in implicit learning tasks, the awareness task typically involves probing whether people have metacognitive knowledge about the grammar knowledge, that is, judgment knowledge. Thus, the reason that CR performs very well in implicit learning tasks and that PAS fares better in perceptual awareness tasks may precisely stem from the fact that CR inherently measures metacognitive content and judgment knowledge rather than perceptual awareness in and of itself. When one probes metacognitive content, criterion content becomes crucial, in that you are precisely interested in what people know about *why* they gave a particular response.

Does this line of reasoning entail that PAS is indeed, as Dienes and Seth (2010) suggest, not exclusive? Yes and no. One would be inclined to answer "Yes" if one is interested in judgment knowledge, as people may report awareness below a level that they can consciously link with the judgment task. PAS thus reflects knowledge located below a task-relevant level. One would be enclined to answer "No", however, if one is interested in perceptual content, irrespective of whether people can causally link it to their task performance. What this shows is that the criterion content and exclusiveness of a particular awareness measure lie on a sliding scale: the more emphasis is put on criterion content or on judgment knowledge, the less exclusive subjective reports may turn out to be, since they will always be sensitive to information that people cannot link to their performance.



## Conclusions and perspectives

What can we conclude from this brief overview? The challenge of measuring awareness based on behavioral measures, despite the substantial progress achieved over the years, remains essentially intact. We do not and cannot have direct access to people's subjective experience, and hence have to rely instead on potentially biased reports or on indirect evidence obtained through behavior. These measures are plagued by different thorny issues that we have attempted to analyze here. All measures of awareness entail complex issues related to Newell and Shanks' criteria: relevance, immediacy, sensitivity, and reliability. The assessment of awareness requires carefully excluding potential confounds:

performance, priors, and the very act of reporting. Any direct measure necessarily involves the observer paradox: asking people to reflect upon their own experience or their own behavior changes the very processes we are measuring (i.e. awareness simply cannot be "turned off"). Objective measures suffer from the contamination problem: they can be influenced both by conscious and unconscious contents, just as subjective measures. Establishing unconscious cognition requires designing paradigms in which the strength/efficacy can be adequately addressed; that is, paradigms that successfully make it so that the stimulus is strong enough to exert detectable effects on performance, yet weak enough that participants fail to become aware of it.

These different caveats remind us of two central issues in the study of consciousness. First, details matter. One cannot emphasize enough how apparently small differences in procedures may lead one to strikingly different conclusions when it comes to distinguishing between conscious and unconscious cognition. Second, theory matters. Our methods are never independent from theoretical considerations, for different theories of consciousness entail different assumptions about the expected relationships between behavior and awareness.

This outlook may seem overly pessimistic, yet the field as a whole, as we have attempted to document, has witnessed tremendous progress over its short history. As for now, the best strategy seems to us to consist of carrying out (1) systematic comparisons between different measures so as to develop a better understanding of the conditions under which associations or dissociations between behavior and awareness are observed, and (2) systematic comparisons between processing with and without consciousness.



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