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Is conscious perception gradual or dichotomous? A comparison of report methodologies during a visual task ☆

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Abstract

In a recent article, [Sergent, C. & Dehaene, S. (2004). Is consciousness a gradual phenomenon? Evidence for an all-or-none bifurcation during the attentional blink, *Psychological Science, 15*(11), 720–729] claim to give experimental support to the thesis that there is a clear transition between conscious and unconscious perception. This idea is opposed to theoretical arguments that we should think of conscious perception as a continuum of clarity, with e.g., fringe conscious states [Mangan, B. (2001). Sensation's ghost—the non-sensory "fringe" of consciousness, *Psyche, 7*, 18]. In the experimental study described in this article, we find support for this opposite notion that we should have a parsimonious account of conscious perception. Our reported finding relates to the hypothesis that there is more than one perceptual threshold [Merikle, P.M., Smilek, D. & Eastwood, J.D. (2001). Perception without awareness: perspectives from cognitive psychology, *Cognition, 79*, 115–134], but goes further to argue that there are different "levels" of conscious perception.

Keywords: Consciousness; Perception; Awareness; Scaling; Measurement

1. Background

In a recent article published in *Psychological Science*, Sergent and Dehaene (2004) argue that the distinction between conscious and unconscious perception is dichotomous, and that a sharp transition can be identified between the two. Their argument is opposed to the view that there is a continuum of the "clarity" with which a perception is conscious (Mangan, 2001). Their argument is based on three experiments in which subjects use a continuous scale in an all-or-none fashion.

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In the reported experiments, Sergent and Dehaene investigate the attentional blink as first described by Broadbent and Broadbent (1987). The attentional blink refers to the phenomenon that the identification of a stimulus hinders an explicit report of a second stimulus if the two are temporally separated by between 200 and 500 ms. Sergent and Dehaene investigate whether the attentional blink degrades the clarity of the second stimulus or whether it corresponds to an all-or-none loss of conscious perception. In all stimulus-present conditions, the stimulus was a four-letter number word. Stimulus-absent conditions also occurred. Subjects were asked to rate, on a continuous scale, how visible the second stimulus was. Two labels were displayed at each end of the scale: ''not seen'' at the left and ''maximal visibility'' at the right. The rating was performed by moving a cursor on the scale in order to point out exactly how visible the stimulus was.

In Experiment 1, the second stimulus was presented following a lag of between 86 and 688 ms after the first stimulus. The visibility scale was presented after each presentation, after which the subject was also asked to report what was presented (one of two possible words). The experiment showed that the subjects used the scale as a dichotomous report rather than a continuous scale. Sergent and Dehaene conclude that the attentional blink consists of an all-or-none loss of conscious perception of the second stimulus.

Sergent and Dehaene suggest that a possible confound in Experiment 1 could be that the subjects have a bias toward the ends of the scale. In the second experiment, subjects were presented with the stimulus word for 14–86 ms duration followed by a mask. Here, they found that subjects rated visibility in a more continuous manner than in Experiment 1, indicating different mechanisms behind the attentional blink and degraded perception induced by masking.

In a third experiment, the attentional blink and masking were combined. The stimulus was presented as in experiment one, but was followed by a blank screen for 129 ms, after which the second stimulus was presented, followed by a mask. The attentional blink was found still to give rise to all-or-none response patterns.

The three experiments leave Sergent and Dehaene with two method-dependent results. When using the attentional blink procedure, subjects tend to respond in an all-or-none fashion, whereas when using a masking procedure, subjects respond in a continuous manner. In the discussion, Sergent and Dehaene argue that the two-stage model of stimulus processing offered by Chun and Potter (1995) provides the best explanation of data. According to Chun and Potter, the attentional blink phenomenon indicates that the second stimulus cannot be fully processed as the first stimulus still fills up the ''narrow channel of perceptual processing''. They argue that non-dichotomous reports indicate that some aspects of the stimulus achieve perceptual threshold but that conscious perception is still a matter of ''all-or-none''. This is especially a possibility when using words as stimuli: we cannot assume that a word is processed as a ''gestalt'' where all letters reach same level of processing. Based on this interpretation of the two lines of result, Sergent and Dehaene conclude that conscious perception is dichotomous. It does however seem strange that Sergent and Dehaene argue strongly in favour of this interpretation: when having two experimental set-ups giving rise to two different lines of result, one should be cautious just explaining away one line of result based on a theory favouring the other line of result.

We believe that Sergent and Dehaene, in these experiments, have not taken several pertinent factors into account in their recording of subjective experiences. We think that Merikle and Reingolds' (1998; Reingold and Merikle, 1988, 1990) criticism of dichotomic measures of awareness apply to the study by Sergent and Dehaene. Using the dichotomic measure of perceptual awareness, Sergent and Dehaene cannot rule out that (1) they have assessed all relevant consciously perceived information, and (2) that their use of subjective reports can demonstrate a true 'null sensitivity', i.e., that subjects, when reporting no stimulus awareness, still may have some minimal conscious perception. If this cannot be ruled out, some level of residual awareness may still have influence on data even though no awareness is reported (Merikle & Reingold, 1998).

Merikle and Reingold (1998; Reingold and Merikle, 1988, 1990) have proposed that one solution is to use comparable direct and indirect measures of perception or memory. For example, one might ask a subject to perform either a recognition or preference task. Asking the subjects to report whether they can recognise an item is a 'direct task', since we are using a measure of experience (of item memory). On the other hand, asking the subject to choose the item (from a set) that they prefer, is an indirect approach. Here, no reference is made to previously shown items, which is done explicitly in the recognition task. This approach is claimed to have an advantage over dichotomic measures in that it puts less conceptual constraints about what is studied. All that needs to be assumed is that ''the sensitivity of the direct measure to conscious-perceived, task-relevant infor-

mation is equal to or greater than the sensitivity of the indirect measure to the same information'' (Merikle & Reingold, 1998). An unconscious influence is assumed when an indirect measure is more sensitive than a comparable direct measure to the same kind of perceptual discrimination.

While Merikle and Reingold argue for the use of two behavioural measures of stimulus awareness, others have suggested that it is possible to develop and use more elaborate and descriptive approaches of perceptual awareness (e.g., Overgaard, Gallagher, Varela, Lutz, Roepstorff and Marcel). Ramsøy and Overgaard (2004) had subjects create their own categories for subjective reports during long training sessions. As in Sergent and Dehaene, subjects were asked what they were shown and how they experienced the stimulus in terms of clarity. Here, stimuli were simple visual figures (triangles, circles or squares) presented in one of three possible colours (blue, green or red). Subjects conformed to a four-point scale categorised as ''not seen'', ''weak glimpse'' (meaning ''something was there but I had no idea what it was''), ''almost clear image'' (meaning ''I think I know what was shown'') and ''clear image''. When subjects tried to use more than four categories in the scale, they found it confusing and quickly abandoned the extra categories. In the experiment, after the category-generating training process, subjects found the categories easy to use, and they used them in a ''continuous manner''. It is important that stimuli in this experiment differed from the stimulus material used by Sergent and Dehaene. Ramsøy and Overgaard (2004) used simple, geometric figures and colours, which do not show up ''one element at the time'' as a word may. Thus, the explanation of our subjects' continuous reports is hardly the one offered by the two-stage model of stimulus processing.

Using the four-point scale (named the Perceptual Awareness Scale, or PAS), subjects were shown the same stimuli for almost 2 s while being stimulated over ventral regions with transcranial magnetic stimulation (TMS) (Overgaard, Nielsen, & Fuglsang-Frederiksen, 2004). In this experiment, subjects demonstrated no decrease in their ability to report correctly with regard to the stimulus; however, they reported a decrease in experiential clarity when TMS was delayed by 110–120 ms after the stimulus presentation. Thus, continuous reports have been shown using other methodologies than masking.

When using PAS, it has been considered imperative that subjects be clearly instructed that they are to report ''introspectively'' (Ramsøy & Overgaard, 2004). That is, they are to report about what they experience rather than report about stimulus features. Overgaard et al. (2004) demonstrated, as mentioned, that correct reports about stimulus features can be dissociated from reports about experience. The instruction about ''stimulus visibility'' used by Sergent and Dehaene is ambiguous and can be interpreted introspectively as well as non-introspectively.

Furthermore, we find the subjective scale used by Sergent and Dehaene to have inherent flaws. As only the extremes of the scale are labelled with descriptions, responses between the extremes (shown as a continuous line) are ambiguous, more difficult to use for the subject, and difficult for the experimenters to accurately interpret. The finding that subjects responded more often at the ends of the scale (i.e., in an apparently dichotomous manner) seems not entirely surprising given that the two extremes of the scale were the only two responses that were defined, and with nineteen other (un-labelled) response level options between them it seems logical that the number of responses at each of these levels would be relatively low, spread out thinly between the extremes as they are. Furthermore, it has been demonstrated (Ramsøy & Overgaard, 2004) that use of more than four response categories in measuring subjective awareness does not produce any more useful data, and may serve only to confuse subjects; thus the 21 contiguous positions used by Sergent and Dehaene, with only a description at each extreme, would be unlikely to produce meaningful data. Were respondents given only four possible response levels, the data may have looked very different.

While these difficulties call for further experiments on the matter, they do not explain why Sergent and Dehaene found dichotomous responses when using the attentional blink procedure. We believe that this is easily accounted for in reference to the stimulus material rather than to a general theoretical statement that ''conscious perception is a matter of all-or-none''. If the second stimulus used in the attentional blink procedure had all the necessary attributes in both duration and clarity for full conscious perception, subjects would of course respond ''maximal visibility'' every time they saw it. We believe, furthermore, that Sergent and Dehaene are correct to suggest that when subjects miss the second stimulus, it is related to overload in an attentional buffer. This situation would naturally give rise to ''none-or-all responses'' even though the nature of conscious perception might still be continuous. If this interpretation is correct, the attentional blink procedure is not a sound methodological choice when investigating the nature of conscious perceptions.

These problems seem to call for further experiments on the matter. In the experiment reported below, we attempt to account for the mentioned difficulties. We apply PAS to a visual task methodologically comparable to the task for which PAS was originally designed. If we are correct in our criticism, this would remove the tendency for reports to group at the end points of the scale. However, if conscious perception is truly dichotomous, one should expect the same kind of grouping at the end points (as the middle categories do not represent anything real—regardless of how many there are to choose from). Also, we compare the results to another condition where subjects are forced to report in a dichotomous fashion. If conscious perception is dichotomous "in nature", this would have little influence on the results, and subjects would find such a scale more comfortable to use, which we asked them afterwards.

Regarding stimulus material, we use a set-up where a target stimulus must be selected. The task almost suggests an "all-or-none" kind of report, which would make a report of "in between states" a stronger finding accordingly. Our choice of stimulus material stays clear of the kind of explanation Chun and Potter (1995) offer to account for the attentional blink, as it hardly can be experienced "one element at the time" as words can be experienced one letter at the time. A report of an "in between" state would in this paradigm represent a report of the nature of the experience (how vague or clear it is to the subject) rather than a combination of fully conscious and fully unconscious parts. The subjects are asked to report introspectively, that is, to report about their own experiences rather than about stimulus features.

2. Method

Fourteen subjects (5 male, 9 female, age between 18 and 65, mean 35.2) participated in the study. All subjects had normal or corrected-to-normal vision.

Stimuli were textured displays also used by Kolb and Braun (1995) but as grey lines on white background instead of white lines on black background as white on black was found to result in an overly early ceiling effect due to high perceiver sensibility. The images consisted of a series of oriented-element textures. The "target" consisted of four orthogonal elements in one of the four possible quadrants as shown in Fig. 1. The shortest stimulus duration was 12 ms, and multiples of 12 ms for longer durations were determined by the 85 Hz monitor refresh rate. Images of 450×450 pixels produced 182×182 mm figures on the screen. A mask, displayed

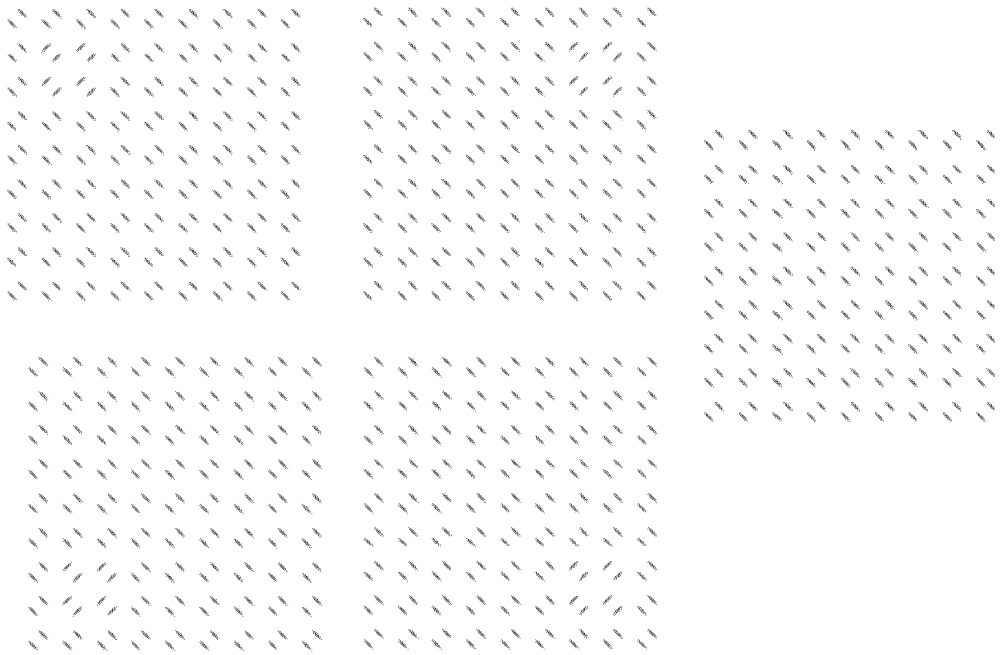

Fig. 1. The randomly presented stimulus images.

for 500 ms before the target stimulus and 800 ms after, consisted of an image of overlapping orthogonally oriented lines.

Subjects were asked to give introspective reports about where they perceived the orthogonal lines. They were instructed to guess, if they did not see it. Each subject was initially given three blocks of 20 stimuli as training. Initially, subjects were presented with very long durations (250, 350, and 450 ms) so they could get a clear feeling of what was going on and what stimuli were like. Using the "method of limits" (originally developed by Fechner), subjects were given still shorter durations to get used to the briefer durations. In the actual experiment, subjects were given stimuli at duration times of 12, 24, 36, 48, 72 and 96 ms. Some subjects who had difficulties producing meaningful data at these durations were not given the 12 ms. stimuli and a 120 ms stimulus instead. With this modification, subjects produced very similar data. Subjects were not given the exact same amount of stimuli in the different durations due to the randomization, but no significant differences were found between the distributions of stimulus durations between subjects.

The four points of the PAS were formatted to fit the actual experiment as follows:

1. *No experience*. No impression of the stimulus is experienced. All answers are experienced as mere guessing.
2. *Brief glimpse*. A feeling that something was present, even though a content cannot be specified any further.
3. *Almost clear experience*. Feeling of having seen the stimulus, but being only somewhat sure about it.
4. *Clear experience*. Non-ambiguous experience of the stimulus.

In the brief interview after the experiment, the subjects reported no problems using the scale with this task.

Even though PAS was developed for use in a different experimental setting (Ramsøy & Overgaard, 2004), we found the necessary re-definitions of the categories to be so insignificant that no pilot studies focusing on this issue were found to be necessary. This was confirmed by the data in such a way that PAS ratings predicted correctness almost identical to the previous studies (Ramsøy & Overgaard, 2004; Overgaard et al., 2004).

The experiment was run in three conditions.

Condition 1. Keyboard response with dichotomous awareness ratings (160 trials per subject). Subjects were instructed to give a numeric keypad response as to where the target had been, after which subjects rated their level of subjective awareness of the stimulus. Subjects pressed one of two keyboard buttons labelled "no" and "yes" as to whether they had seen the stimulus. The response was prompted by the message "Image seen? No or yes?" on the screen.

Condition 2. Keyboard positional response with PAS ratings (240 trials per subject). Here, subjects were asked to rate their level of subjective awareness using the PAS as mentioned above. The scale was explained to each subject and a copy was left with them to refer to if needed.

Condition 3. Verbal responses with PAS ratings (160 trials per subject). Subjects were asked to give verbal reports in a set-up otherwise identical to condition 2. Responses were recorded as .wav files using a microphone.

After the experiment, subjects were given a short questionnaire to ascertain details, such as how they understood the different scales and how they felt using them.

3. Results

3.1. Relation between display time and PAS awareness score

The association between display time and PAS score can be described using an ordinal regression model (ORM) (Harrell, 2001) which is a generalization of the logistic regression model to be used when the observed response is ordered and categorical. Since PAS rating was reported either verbally or using a keyboard we fitted an ORM with display time and report type as factors. Display time was found to be a significant factor ($p < .0001$) with an odds ratio of 4.19 for a 10 ms increase in duration. This means, e.g., that a 10 ms increase in display time improves the probability of a PAS rating of 3 or 4 by a factor of four. Although the mode of report was also significant ($p = .0026$) the estimated keyboard/verbal odds ratio of 0.81 indicated that the

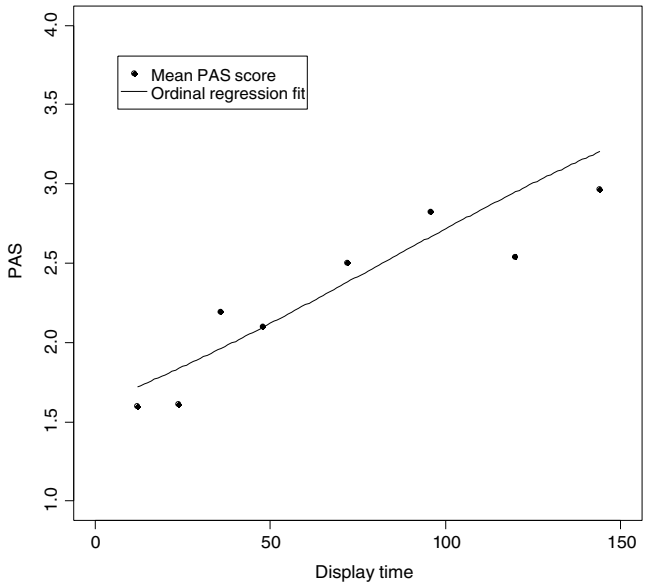

Fig. 2. The relation between PAS and stimulus display time.

difference is of no practical concern. Fig. 2 illustrates the relation between display time and PAS rating. Dots indicate mean PAS score over all subjects and the curve shows the estimated PAS score as a function of display time in the fitted model.

3.2. Relation between PAS awareness score and probability of correct answer

In order to describe how the probability of a correct answer depends on reported PAS level we used a logistic regression model. Again since PAS level was reported in two ways we adjust for this effect by including it as a factor in the model together with the actual PAS rating. We found that report modality is insignificant ($p = .98$) while PAS score is highly significant ($p < .0001$). Fig. 3 summarizes the dependence between PAS and probability of correct answer.

We note that the probability of correct answer ranges from almost pure chance at PAS level 1 (probability of correct answer is 31%) to almost certain at PAS level 4 (probability of correct answer is 94%).

For comparison we also fitted a logistic regression model to the dichotomous response data, see Table 1.

The probability of a correct response when the image was reported 'not seen' (35%) is slightly higher than at the lowest PAS level. However, the probability of correct answer at the highest PAS level (94%) was substantially higher than when subjects reported 'image seen' (78%).

3.3. Uniqueness of the PAS scale

It may be speculated that collapsing PAS levels 1–2 and 3–4, i.e., transforming it into a two-point scale would essentially lead to a scale identical to the dichotomous scale. We addressed this problem by calculating for each level of PAS the percentage of cases in which subjects answered 'image seen' when reporting dichotomously (but presented with identical stimulus at equal display time). The results shown in Fig. 4 indicate that in more than 20% of the cases where subjects reported a PAS score of 1 they (paradoxically) responded 'image seen' on the binary scale. Furthermore, given a subject reported PAS level 2 the probability that he would answer 'image seen' on the dichotomous scale is 39%. We therefore infer that instructing subjects to report using a continuous scale leads to a fundamentally different responses that cannot be compared with reports from the objective 'image seen/not seen' scale.

No significant differences were found related to age or gender.

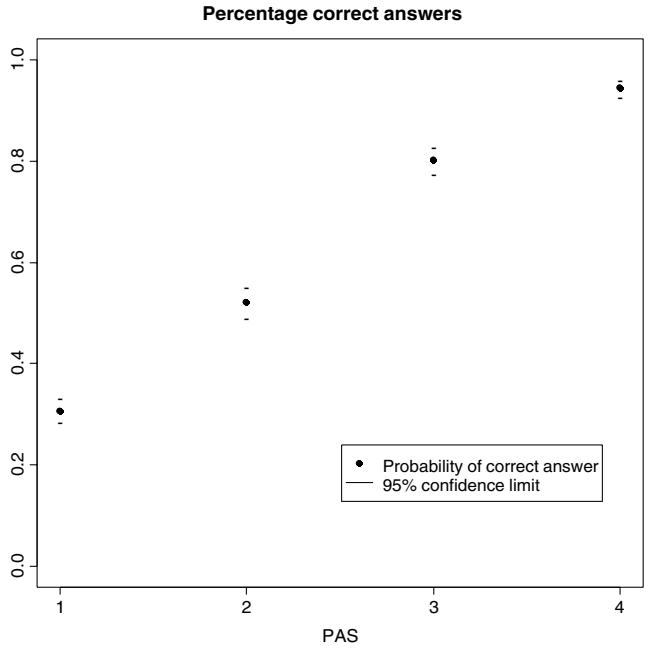

Fig. 3. The relation between PAS and probability of correct response.

Table 1
The relation between dichotomous report and probability of correct response

	Lower CL	Prob correct	Upper CL
Image not seen	0.33	0.35	0.38
Image seen	0.75	0.78	0.80

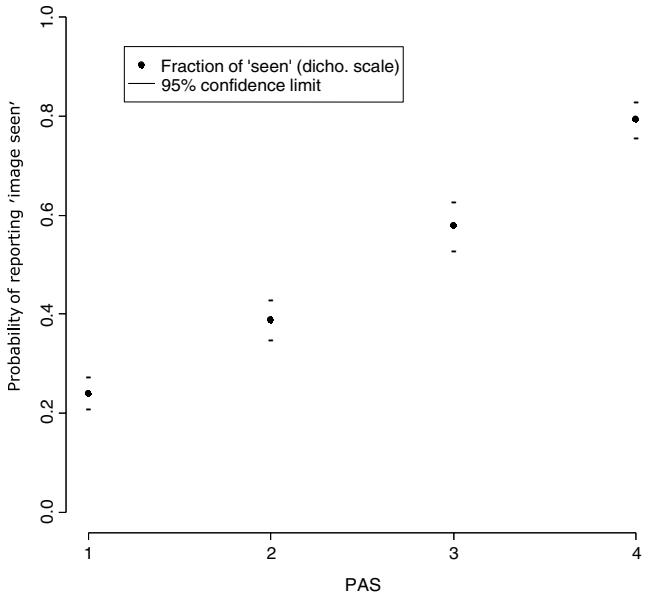

Fig. 4. Comparison of dichotomous report and PAS scores. For each level of PAS we calculated the number of times a subject responded 'object seen' in the corresponding dichotomous paradigm.

4. Discussion

It seems a reasonable assumption that PAS ratings should correlate with other relevant measures such as display time and correctness. As it is evident in Figs. 2 and 3, this is indeed the case. Furthermore, PAS does not change substantially as a function of report modality, which, we believe, is a further consolidation of the measure.

The strongest line of evidence for the validity of the PAS scale as a reflection of conscious perception is however the subjects' own reports that it is the case. Furthermore, subjects often reported that the dichotomous measure was more difficult to use, even though it should seem simpler in terms of numbers in the scale.

One could of course argue that the correlation with correctness is not sufficient independent support for the validity of PAS: PAS may predict performance, but our conclusion is about consciousness. It could thus be argued that there is a possibility of circularity in that the main support for the measure of the subjective state is the subjective report. Contrary to this, one may claim that the use of reports to measure subjective states is fundamentally unavoidable. Other studies using, e.g., recognition as measure of conscious perception (Kunst-Wilson & Zajonc, 1980) must also justify the relation between recognition and subjective state by way of a report that such a relation exists. Thus, we argue, there is no way around subjective measures when arguing that some behavioural measure is related to consciousness. If, say, recognition as a measure of consciousness can validated by use of subjective reports, those reports are considered a direct measure of consciousness in the same way as they are in our study.

Kihlstrom, Barnhardt, and Tataryn (1992) and Kunzendorf and McGlinchey-Berroth (1997–1998) suggested that subliminal stimuli are above the threshold differentiating conscious from unconscious stimulation but are below the threshold for self-conscious apperception. Following this argument, our "in-between" states would represent states that are fully conscious of the stimulus and fully unconscious of themselves, seeing the stimulus. Whereas such an interpretation cannot be ruled out, it seems to be a less obvious. Since the subjects did report some awareness, and since the suggested line of interpretation seems to indicate that subjects will only report having seen something if they are aware of the fact that they in fact did see it, it must be argued that subjects were "partially self-conscious" while being fully perceptually conscious. This interpretation, in other words, will also admit a graduation of consciousness, just not of conscious perception.

Prior to our study, it has been argued that there are two different awareness thresholds—an objective and a subjective one (Merikle, Smilek, & Eastwood, 2001). These two thresholds reflect three distinguishable states: up to the first, there is no registration of stimulus. Between the first and the second threshold there is no subjective experience but there may be implicit processing. Above the second threshold, there is conscious perception. Whereas this idea clearly is in line with the results of the above described study, we find evidence to take a further step and argue that there are different "kinds" or—perhaps—thresholds of conscious perception.

While our results using PAS overlap with the results of Sergent and Dehaene using the continuous scale, there are both objective and subjective arguments for choosing PAS. As for the objective arguments, as mentioned, the high amount of positions on the scale results in a "smearing" of all data between the two ends of the scale. This tendency also indicates a poor match between kinds of subjectively recognizable perceptual states and the vast number of response options. This leads us to the subjective argument that experimental subjects originally formed the PAS scale and that they in post-experimental interviews report a good match between their experiences and the positions on the scale.

With regards to the more general issue whether we should conceive of conscious perception as an all-or-none or a continuous phenomenon, we find it a logical answer that if subjects report degrees of conscious awareness in some but not all kinds of experimental set-up, this is sufficient evidence that conscious perception is a continuous phenomenon. It would be, we find it, a more scientific sound explanation that some methods do not capture "in-between degrees" of experience than it would be to explain away that subjects report such degrees using other methods. In the present case, both the masking study reported by Sergent and Dehaene and our own PAS study indicate degrees of conscious awareness. Furthermore, using PAS we find it reasonable to say that there is as good evidence for the "in between" kinds of perceptual states as for the states represented by the ends of the scale, as data cannot be said to lend more support to the existence of the last than of the first kinds of states.

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