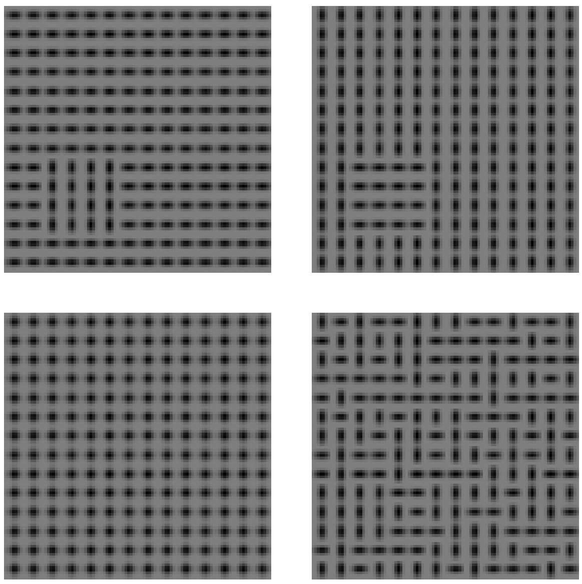
"BLINDSIGHT" IN NORMAL SUBJECTS?

M.J. Morgan
A.J.S. Mason
J.A. Solomon
(Institute of Ophthalmology, University College London)

Address for correspondence:
Michael Morgan
Department of Visual Science
Institute of Ophthalmology
University College London
Bath Street
London EC1V 9EL
Fax: 44-171-608-6830
email: m.j.morgan@ucl.ac.uk

Blindsight[1] is the condition in which patients with damage to the visual cortex of the brain nonetheless have residual visual sensitivity[2] in a subjectively blind part of the visual field. Such patients are able to carry out tasks such as pointing to a light in the blind area, but their verbal reports indicate no awareness of the presence of the stimulus. Kolb & Braun[3] report an intriguing parallel to blindsight in normal subjects, who were briefly shown a pattern in which part of one quadrant of the display had a contrasting texture which "popped out" from the rest of the pattern (see Fig. 1). When this texture pattern, viewed by one eye, was masked by a complementary pattern in the other eye, subjects' ratings of subjective confidence in their ability to detect the texture contrast showed no correlation with their success rate, whereas in the unmasked condition their confidence was highly related to their success rate.

A) Right Eye B) Left Eye



C) Right Eye + Left Eye D) Post-Stimulus Mask

Fig. 1: Schematic versions of the patterns used to test 'blindsight' in human observers. A patch within the target quadrant contains texture elements rotated by 90 deg with respect to those in the rest of the pattern. In the *unmasked* (monocular) condition the pattern (**A** or **B**) is presented to one eye only, with a blank field of mean luminance presented to the other eye. In the *masked* (dichoptic) condition a pattern is presented to one eye and its inverse, wherein all elements are rotated 90 deg, is presented to the other eye. **C** shows the view of the screen when the two eyes' patterns are combined. These were not the actual patterns used in the experiments: full details are given in the Methods section. The post-stimulus mask (**D**) was absent in Experiment 0.

In Experiment 0 we attempted to replicate Kolb and Braun's procedure using the same stimulus geometry, contrast and display duration (250 msec presentations without post-stimulus mask). Trials of the masked (dichoptic) and the unmasked (monocular) conditions were interleaved. The subjects were the three authors. As Fig. 2 shows, all subjects were virtually 100% correct in the unmasked condition. One subject's (AJSM) performance did not exceed the chance level (25%) in the masked condition. The other two subjects were more successful. They were more likely to be correct when they selected high confidence ratings than when they selected low confidence ratings. Their results show no evidence of blindsight.

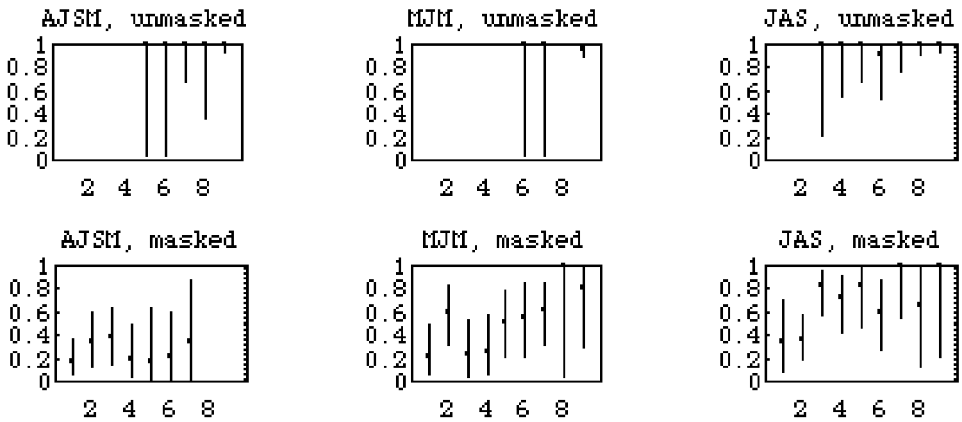


Fig. 2: Results of Experiment 0. Each plot gives the proportion correct as a function of confidence rating. Error bars indicate 95% binomial confidence limits. In general, responses were more likely to be correct when confidence was high than when confidence was low.

It was apparent from Experiment 0 that to obtain similar performance levels in the masked and unmasked conditions we would have to tailor the displays to the individual subjects' abilities. In Experiment 1 we used slightly different stimuli (Methods) and measured full psychometric functions relating percent correct to each of five exposure durations. Success rate in each condition was determined using exposure durations individually chosen to produce a range of performances between chance and 100%. In Experiment 2, which included naive subjects, the task from Experiment 1 was made somewhat easier by 1) presenting first the unmasked condition and then the masked condition, in separate blocks; 2) enlarging the target to fill the whole of one quadrant; and 3) requiring the subject to guess only the side (left or right) on which the target was located. All subjects had normal or correctedto-normal vision, except for MC who had an uncorrected astigmatism in one eye. We thought that she might serve as a useful control for possible suppression of one eye, but her results were not obviously different from those of other subjects.

In Experiments 1 and 2 observers could identify the unmasked target after exposures of about 100 msec (followed by a post-stimulus mask), and two of the subjects (AJSM and JL) could also identify the target after similar exposures in the masked condition. They reported that the target did not appear to differ in orientation from the background (inconsistent with suppression of one eye as an explanation) but it did seem to differ in brightness or depth (possibly resulting from false stereo matching).

The other subjects required longer exposures to see the target in the masked condition. JAS also saw the target as being defined by brightness or depth, while MJM and DIAM saw something like a line surrounding the target. We presume that these verbal reports are post hoc rationalizations for the segmentation of the image without an orientational cue. Clearly, the experience, although vague, is not unconscious. This is also demonstrated by the high correlation of the subjects' mean confidence ratings at a given exposure duration with their success rate (Fig. 3 and Table), a result quite different from that reported by Kolb & Braun. There was also a high correlation when the data were collapsed across exposure duration, and the success rate was calculated separately for each of the ten points on the confidence scale.

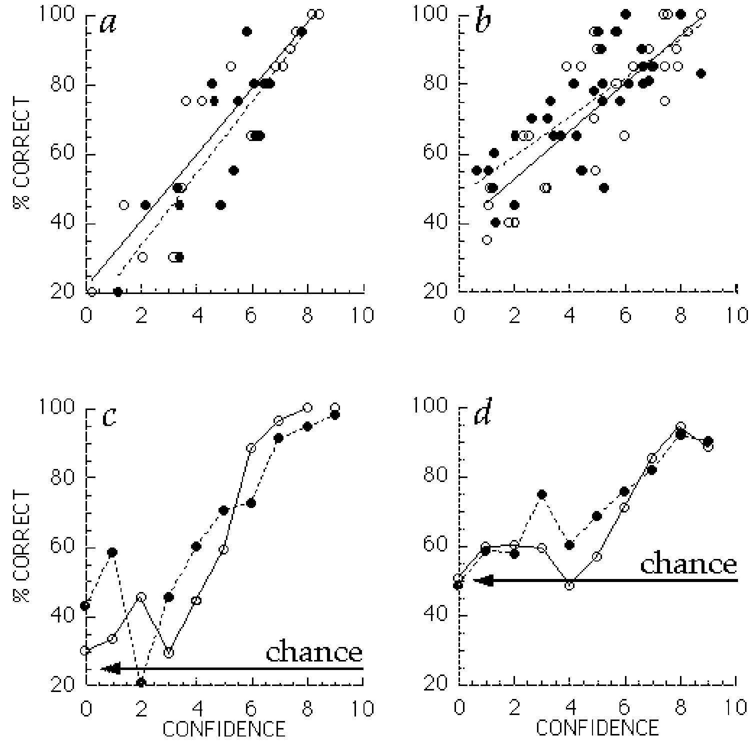


Fig. 3: Correlation between success and confidence of success. Each point in panels *a* and *b* represents the performance of an individual subject at a particular exposure duration, in either the masked (solid symbols) or the unmasked (open symbols) condition. Linear regressions are shown (masked condition, broken lines; unmasked condition, solid lines). All correlation coefficients are high (*a*: masked .84, unmasked .92; *b*: masked .77, unmasked .92). In Experiment 1 (*a*) the subjects were the three authors and masked and unmasked trials were randomly interleaved. In Experiment 2 (*b*) the two conditions were blocked and the subjects included 3 naive observers. Further observations were carried out on one other experienced subject (DIAM) in the masked condition alone (see Table). Procedural details are available upon request, contact MJM. Panels *c* and *d* replot the data from panels *a* and *b*, respectively. Each point represents the mean for all of the subjects, collapsed across exposure duration. Irrespective of duration, confidence is still a good predictor of success rate in both unmasked and masked conditions.

TABLE

Correlations of % correct with mean confidence rating

Subject	Unmasked	Masked
MC	0.99	0.77
FF	0.76	0.97
MJM	0.90 (0.96)	0.99 (0.92)
AJSM	0.95 (0.98)	0.99 (0.94)
JAS	0.87 (0.90)	0.91 (0.85)
JL	0.89	0.73
DIAM	-	0.95

(The figures in parentheses show the results from Experiment 1)

Kolb and Braun used only a single exposure duration (100 or 250 msec) within a block. Our use of a wide range of exposures within a block may have encouraged subjects to use their confidence ratings in a more meaningful fashion. Kolb & Braun's subjects were instructed to use the full confidence scale, irrespective of their absolute sense of certainty. If they were reluctant to use the vague cues in the masked condition as evidence for a high-confidence judgment, they may have decided to produce ratings randomly, with the result that Kolb and Braun observed. It is otherwise difficult to understand why they made errors on trials when they claimed to be highly confident: the opposite of blindsight.

Although we do not confirm Kolb and Braun's claims about blindsight we agree that the target can be identified in the masked condition without a phenomenal orientation cue. We also agree that the masked target is more vaguely defined than the unmasked one, and in some respects harder to identify, although we do not agree that it fails to reach awareness. The fact that the target can be identified at all implies that texture boundaries can be identified by a monocular process, presumably in the primary visual cortex V1, since neurons in other visual cortical areas such as V2 are exclusively binocular in the area of the visual field seen by both eyes. It would appear that the position of these boundaries can be made explicit, even though later stages of binocular processing are unable to determine what it is that these boundaries divide in the image. We have recently found similar results with different coloured elements in the two eyes (isoluminant R vs G), in agreement with the classic demonstration that retinally-disparate squares in the two eyes can yield an impression of stereoscopic depth despite simultaneously showing colour-rivalry.[4]

METHODS

The patterns were displayed on a Barco Calibrator II monitor using a Cambridge Research Systems VSG graphics board. Left-eye and right-eye patterns were presented in alternate video frames (at a monocular frame rate of 60 Hz) and separated by ferro-optical goggles synchronized to the inter-frame interval. Background luminance was held constant at ~20 cd/m^2. In Experiment 0 both eyes viewed a 20 x 20 array (14 degrees square) of circular, cosine-phase Gabor patterns oriented ±45 degrees from vertical, with a center frequency of 2.2 cycles/degree and 0.63 degrees between e^{-1} points. One quadrant contained 4 x 4-element target region, where the Gabor patterns were oriented orthogonally to those in the rest of the array. The contrast of each Gabor pattern was 1.0. Each display was preceded by a vernier target with the two lines in opposite eyes. When properly fused, the lines appeared without an offset. This vernier display was presented for 2 sec before each trial in Experiment 0 (but not Experiments 1 and 2). If the subject was not satisfied with fusion he/she selected a confidence rating of “0” for that trial In Experiments 1 and 2 used a 14 (columns) x 20 (rows) array of dark gaussian blobs (contrast 1.0), each having a 2:1 aspect ratio (0.45 and 0.91 degrees between e^{-1} ponts). 0.48 degrees separated adjacent gaussians. In Experiment 1 the target region was a 4 x 4-element array, whereas in Experiment 2 the target region was the entire (7 x 10-element) quadrant. A post-stimulus mask of 250 msec was presented immediately after each stimulus exposure, consisting of an array of randomly-oriented elements of the same size as the stimulus elements.

In Experiments 0 and 1 the subjects’ task was to indicate the quadrant containing the target region. In Experiment 2 subjects merely had to indicate the side of the display (left or right) containing the target quadrant. After each trial the subject first selected a key to indicate target position, then selected a digit between 0 and 9 to indicate confidence. "0" meant "a pure guess" and "9" meant "certainly correct", except in Experiment 0 where confidence rating 0 was reserved to indicate failure of fusion of the vernier display. Subjects were instructed to use the full scale. No feedback was given.

In Experiment 0 the exposure duration was fixed at 250 msec and masked and unmasked conditions were randomly interleaved. In Experiments 1 and 2 the exposure duration was varied between trials to obtain a psychometric function relating the probability of a correct response to the exposure duration. 20 trials were given at each exposure duration.

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