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A new method to assess eye dominance

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People usually show a stable preference for one of their eyes when monocular viewing is required ('sighting dominance') or under dichoptic stimulation conditions ('sensory eye-dominance'). Current procedures to assess this 'eye dominance' are prone to error. Here we present a new method that provides a continuous measure of eye dominance and overcomes limitations of previous procedures. We presented dichoptic streams of randomly selected alphanumeric characters at rates around 5 Hz and asked observers to detect a particular character. In most subjects, the dichoptic streams of letters did not perceptually overlap, instead many participants were never aware that two letters were always presented. Interocular differences in target detection were evident in most observers, thus targets presented to one eye were always detected while targets presented to the other eye were generally missed. These interocular differences (i.e., eye dominance), were normally distributed and showed high test-retest reliability.

Considering that monocular channels are complexly interconnected structures, subtle differences in anatomy, physiology, or in the pattern of interconections, all of them within the realm of possibilities, might yield interchannel differences in visual information processing.The issue has not attracted attention, except for the controversial (Mapp, Ono, and Barbeito, 2003) and long lived (see Porac and Coren, 1976) eye-dominance concept. Eye-dominance refers to a monocular preference shown when monocular images cannot be fused (for example, during dichoptic stimulation), or when monocular viewing is required (e.g., aiming a rifle). Despite its long history, eye dominance is an unclear concept (Mapp, et al. 2003), partly because most popular assessment methods are contaminated with

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extraneous variables, and partly because no systematic differences in information processing could be associated with eye dominance.

Two types of eye-dominance tests are used. The most popular are the sighting-dominance measures which represent situations in which both eyes cannot be simultaneously used. For example, aligning a finger with a distant point while keeping your eyes opened produces conflicting images and subjects align the finger with one of their eyes (this is the basic Porta's test). It has been shown that handedness and knowledge about what is been measured influence the results (Porac and Coren, 1976). Another situation that requires monocular viewing is peeking through a hole, the basis of ABC test (Miles, 1929, 1930). In its original form, subjects held a truncated cone covering their faces, kept both eyes open and aimed to a distant point. Observers aligned the cone with one of their eyes without realizing it. A more popular version of this test is to look through a hole in a card, or to look through a hole made with your hands. Handedness is not a confounding variable, but the results might be influenced by gaze direction (Khan and Crawford, 2001; Carey, 2001) or retinal size (Banks, Ghose, and Hillis, 2003). It can be concluded that sighting dominance measures are affected by a number of factors, and it is unclear what these measures are addressing.

The alternative method to assess eye dominance is based on binocular rivalry. Confronted with discrepant monocular stimuli, observers first perceive a dynamic mixture of the two stimuli ('piecemeal rivalry') followed by cycles of perceptual dominance and suppression. The perceptual oscillation is generally biased, thus one of the monocular inputs is seen longer (the dominant eye). The sighting measures problems cited above do not play a role here. Instead, problems arise when suppression of one of the images is not complete, or the transition between the two percepts is slow. In these cases, the perceptual criteria may bias the estimate. With this procedure, the proportion of left and right dominants is roughly equal, instead of the usual right dominance prevalence found with sighting-dominance measures.

To avoid the difficulties found with conventional eye-dominance measures, we developed a new procedure. Basically, it consists of dichoptically presenting randomly selected series of alphanumeric characters (1^{o} in size) at around 5 Hz, while observers look for a particular character embedded in one of the monocular series (see Figure 1A). We call this procedure dichoptic rapid serial visual presentation (RSVP, Raymond, Shapiro, and Arnell, 1992). Note that this procedure overcomes the problems associated with sighting-dominance estimates and provides a more objective measure than those based on binocular rivalry.

While we were working in the experiments here presented, it has been reported that rapidly changing the stimulation to one eye renders invisible an static stimulus on the other eye (continuous flash suppression, CFS), for about one minute (Tsuchiya and Koch, 2005) or even several minutes (Fang and He, 2005). The procedure presented here departs from the CFS in that the monocular streams are essentially identical (a random collection of alphanumeric characters) and that transients are binocular and synchronous. Therefore, the interocular differences during the dichoptic RSVP depend exclusively on intrinsic interchannel differences or in the pattern of interocular inhibition.

EXPERIMENT 1

METHOD

Observers. Thirty-one undergraduate students naïve to the purpose of the experiment participated and received academic credits for their participation. All were women with normal or corrected-to-normal vision and ranged from 20 to 31 years old. All but one, were right handed.

Apparatus and stimuli. Stimuli were displayed on a Sony 17SE colour monitor (1024 X 768 pixels, 85 Hz refresh rate) using MatLab and the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) running on an IBM-compatible computer under Windows XP. The background was grey. The observers viewed the display through a mirror stereoscope placed 60 cm away from the screen so that each eye saw its corresponding half of the screen.

On each side of the screen (see Figure 1A) there was a circular region (radius = 3^o) surrounded by a square region textured with black and white dots (8^o × 8^o). The test stimuli were series of 12 lowercase letters (font 'Bookman Old Style', about 1^o in height, and black colour), randomly chosen on each trial, presented at 5 Hz.

Procedure. The experiment was performed in a dimly lit room. There were ten blocks of 30 trials each, with breaks between blocks. On each trial, a randomly selected 12-letter stream was presented to each eye. On half of the trials, one of the series contained an 'x' (target). On the other half, there was no target. The eye to which the target was presented was randomly selected. The location of the target within the series was also randomly selected within positions 4-10. Observers were informed that a target would appear on half of the trials and to press a key if they saw it, and to press another key if they did not.

RESULTS AND DISCUSSION

About half of the observers saw only one letter on each 200 ms presentation and in many cases were surprised to learn after the experiment that two letters were simultaneously presented. This perceptual suppression of one of the monocular streams was constant through the whole trial (2.4 s), since target location within the series did not have an effect on target detection. Some observers detected targets regardless of the stimulated eye, and reported that they saw the two letters superimposed.

Proportions of correct detections, i.e., hits / (hits + misses) for each subject and eye are shown in Figure 1B. False alarm rates were very low and were not further considered because there is no way to attribute them to one of the monocular channels. Figure 1B shows that our relatively small sample covers a wide range of dominance values ranging from complete left dominance to complete right dominance, and the proportion of left- and right-eye dominants is the same. To assess the reliability of the results, 13 observers repeated the procedure 1-2 months later. The individual scores were remarkably similar in the two sessions, as reflected in a high correlation (r^2=0.96).

EXPERIMENT 2

To extend the findings of Experiment 1 we ran another experiment, in a different lab, with a different letter font (uppercase Arial instead of lower case Courier New), letter colour (white instead of black), different stimulus presentation times (150 ms instead of 200 ms), and with a target (a digit) on every trial that subjects had to identify. The sample was much larger than in Experiment 1 to provide a reliable estimation of the distribution of this type of eye dominance in young adults. Finally, we also assessed the relationships between our eye-dominance estimate and a sighting-dominance estimate derived from Miles' test.

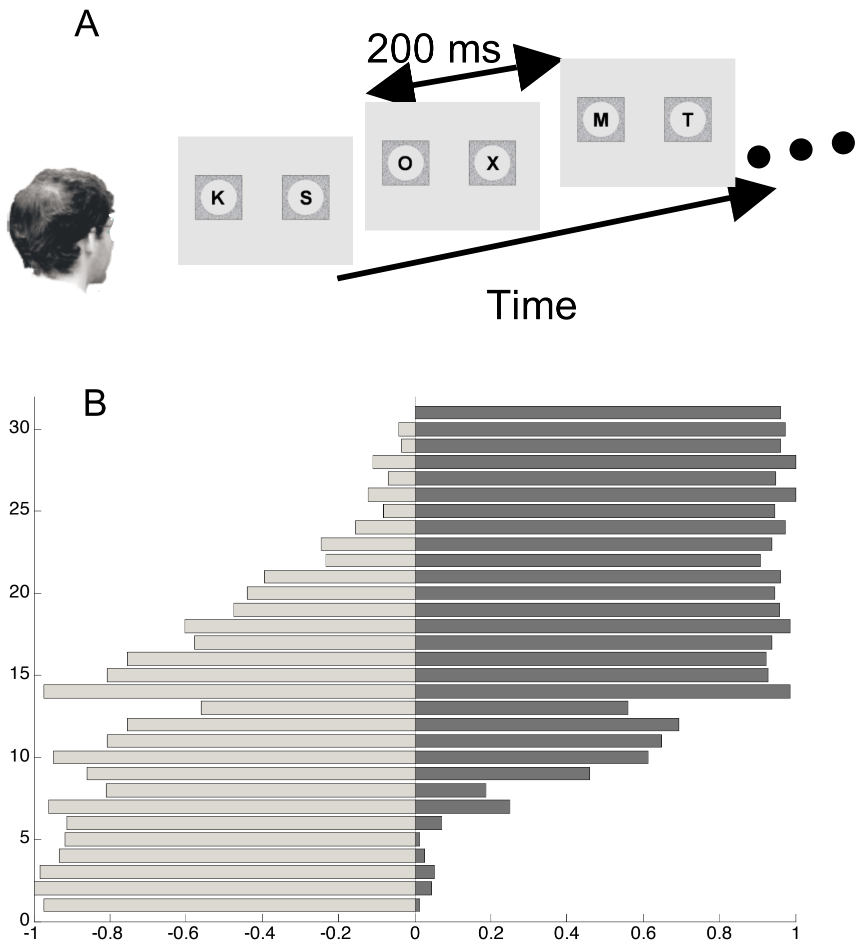

Figure 1. Experiment 1. (A) Schematic stimuli series. Subjects viewed the display through a mirror stereoscope (not shown) and each eye saw a different stream of letters. In Experiment 1, the letters were lower case and presentation time was 200 ms; in Experiment 2, the letters were upper case and the presentation time was 150 ms. (B) Proportion of correct detections for each subject and eye.

METHOD

Observers. Eighty undergraduates of the University of Santiago, 80% of them right handed, with ages between 20 and 37 years old, participated in the experiment and received academic credits. They had normal o corrected-to-normal vision and good stereopsis, and were naïve to the purposes of the research.

Apparatus and stimuli. Stimuli were displayed on an IBM P275 colour monitor (1024 x 768 pixels, 100 Hz refresh rate). The experimental task was programmed with E-Prime V2.0 (Schneider, Eschman, and Zuccolotto, 2002) and run under windows XP on an IBM-compatible computer. The background was grey (luminance = 11 cd/m^2). The observers viewed the display through a mirror stereoscope placed 37 cm from the screen and so that each eye saw only its corresponding half of the screen. The luminance and colour of the stimuli were measured with a CS-100A Minolta photometer.

On each side of the screen (see Figure 1A) there was a circular region (radius = 3^o) surrounded by a square region textured with black and white dots (8^o × 8^o). The test stimuli were series of 12 uppercase letters (font 'Arial', about 1^o in height, and white colour, luminance = 18 cd/ m^2), randomly chosen on each trial, presented every 150 ms.

Procedure. The experiment was performed in a dimly lit room. There were two blocks of 100 trials each, with breaks between blocks. On each trial, randomly selected 12-letter streams were dichoptically presented, one dichoptic pair every 150 ms. One of the letters in positions 5-10 was replaced by a digit between 2 and 9, and participants had to indicate whether it was odd or even. The eye stimulated with the target, and the position of the target within the series were randomly selected.

Observers initiated a trial by pressing a button. Each trial began with the binocular presentation of a central fixation point (18 cd/m^2, 0.2^o in diameter, approximately). 500 ms later the two letter series were presented, with no blank frames between items. The observer indicated whether the target was odd or even by pressing a key on a response box within a time window of 2000 ms. Absence of response was scored as incorrect response.

Sighting dominance was assessed at the end of the experiment. Observers kept both eyes opened and held a card with a hole in the middle with both hands. They had to align the hole in the card with a distant target maintaining their eyes open.

RESULTS AND DISCUSSION

The phenomenal reports were no different from the first experiment. Most subjects were aware of only one letter on each presentation; targets were correctly identified when presented to one of their eyes, and generally missed in the other eye. Observers without eye-dominance perceived the monocular stimuli as superimposed and detected the target regardless of the stimulated eye.

We computed the interocular difference in target detection and divide this difference by the total of trials, i.e., (Right – Left) / (Right + Left); thus negative and positive values indicate left- and right-eye dominance, respectively. There were no effects of target location within the series, suggesting that the suppression of one monocular input is constant through all the observation period (1.8 s). Figure 2A shows the normal probability plot for subjects classified as left- or right-sighting dominants according to the Miles' test. Left-sighting dominants (n=28) tended to score as left-eye dominants in the dichoptic RSVP, and the z scores in interocular difference were normally distributed (r^2=0.95). Right-sighting dominants (n=52) showed more broadly distributed interocular difference scores, also with a normal distribution as shown by a good linear fit (r^2=0.97).

The point biserial correlation between the two dominance estimates was significant (r=0.375; p<0.005). Moreover, our eye-dominance estimates were stable over time (see Figure 2B), as indicated by a high correlation (r^2 = 0.92) between two sessions, two months apart, in a subsample of subjects (n=19).

CONCLUSION

The new method to assess interocular differences (eye dominance) in observers with normal acuity and stereopsis has many advantages over popular sighting measures, and provides a more objective measure than those based on binocular rivalry. The method consists in dichoptically presenting two streams of randomly-selected alphanumeric characters at speeds around 5Hz (dichoptic RSVP) and the observers have to detect a particular character. Under these conditions, many participants are never aware that two letters are always presented, i.e., there is complete suppression of one of the monocular channels. Consequently, subjects typically miss targets presented to one of their eyes and detect all targets presented to the other eye. These interocular differences are normally distributed in the population, as it is common with eye-dominance measures based on binocular rivalry (Ooi, Optom, and He, 2001), and are correlated with sighting-dominance scores obtained with a version of Miles' test.

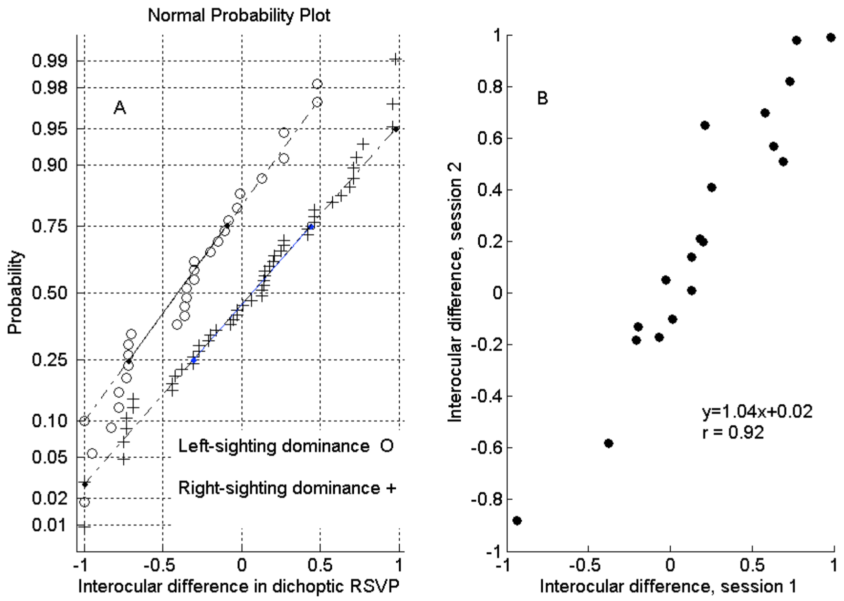

Figure 2. Experiment 2. (A) Normal distribution plots of interocular differences during dichoptic RSVP for left- and right-sighting dominants as assessed with the Miles' test. Each point represents an observer. Superimposed on the plot is a line joining the first and third quartiles (a robust linear fit of the sample order statistics). This line is extrapolated out to the ends of the sample to help evaluate the linearity of the data. (B) Scatter plot of eye-dominance estimates taken two months apart.

The complete suppression of a monocular input under dichoptic viewing conditions has been described with single presentation of target and mask (dichoptic masking, see Breitmeyer, 1984, for a review, and Michaels and Turvey, 1979), during binocular rivalry (see the review by Blake and Logothetis, 2002), flash suppression (Wolfe, 1984), and more recently in the continuous flash suppression technique (Tsuchiya and Koch, 2005). The invisibility produced during dichoptic RSVP differs from all these in that the monocular stimuli have the same characteristics (randomly selected letters with the same size, luminance, and contrast) and are synchronously turned on and off. Therefore, suppression of one channel during dichoptic RSVP must reflect an intrinsic characteristic of the individual visual system, quite possibly rooted in the pattern of interconnections between the monocular channels. It is unclear at the moment whether these presumed inhibitory interconnections are also evident for other stimulus features such as motion or colour, since it is well established the independent access to consciousness for colour and motion (Zeki and Bartels, 1998) form and motion (Andrews and Blackmore, 1999), and form and color (Holmes, Hancock, and Andrews, 2006). It would not be surprising to find that there are differences in eye dominance depending on the stimuli used to assess it. Other issues that deserve to be explored are the influence of retinal location (is eye dominance restricted to foveal regions?) and the fate of the stimulation suppressed from consciousness (can it influence other processes?). We will explore these issues in future experiments, but it is evident from our results that in the route to consciousness, one monocular channel has preference over the other when forms are centrally presented and continuously changing.

RESUMEN

Un método nuevo para evaluar la dominancia ocular . Generalmente, las personas muestran una preferencia estable por uno de sus ojos cuando se requiere visión monocular o bajo condiciones de estimulación dicóptica. Los procedimientos tradicionales para evaluar esa preferencia o dominancia ocular están sujetos a errores. En este artículo presentamos un método que proporciona una medida continua de dominancia y supera muchas de las limitaciones que se encuentran en otros métodos. Nuestro método consiste en presentar, dicópticamente, series de caracteres alfanuméricos seleccionadas al azar, a una frecuencia alrededor de 5 Hz, y pedir al observador que detecte un carácter en particular dentro de la serie. La mayoría de los observadores no percibieron las letras presentadas dicópticamente como solapadas, sino una única letra de cada vez. Diferencias interoculares en detección de targets fueron obvias en la mayoría de los sujetos, de forma que los targets presentados a uno de los ojos se detectaban con facilidad, mientras que los presentados al otro no se percibían. Las puntuaciones de dominancia ocular, o diferencia interocular, obtenidas con nuestro método muestran una distribución normal y una alta fiabilidad test-retest.

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