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Inhibitory effects in the detection of 1 cpd j_o targets superimposed to angular frequency stimuli or sinewave gratings

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Abstract

Independence among channels processing different aspects of spatial information, including orthogonal stimuli, has been generally assumed in the literature. We tested independence between the processing of j_o targets and the processing of either vertical sinusoidal gratings or angular frequency stimuli with suprathreshold summation. We found the detection of a j_o target at 1 cpd to be affected in an inhibitory fashion by either background angular frequencies in the range of 3-96 cycles or sinewave gratings in the range of 0.8-3.0 cpd. These results demonstrate interactions both among orthogonal stimuli and among channels processing vertical sinewave gratings and j_o target stimuli. Our discussion focuses on the hypothesis of frequency decomposition in polar coordinates.

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Key words
- Spatial frequency
- Multi-channel independence
- J_o targets
- Angular frequency filters
- Radial frequency filters

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Independence between channels tuned to orthogonal stimuli (e.g., orthogonal sinusoidal gratings) has been a common assumption in spatial vision research mostly based on physiological and psychophysical studies showing evidence for channel selectivity for both spatial frequency and orientation (1-7). The McCollough effect (8), for instance, has been taken as a clear example of independence between channels processing simultaneously color, spatial frequency and orthogonal orientation. In the context of the "Lie-transformation-group theory of neuropsychology (LTG/NP)" (9-11), a McCollough effect was observed to take place simultaneously for the existence of at least "three independent pattern-generating 'channels'" (10, p.14), that act according to theoretically predicted orthogonal pairs: i) a pair of horizontal and vertical gratings, ii) a pair of hyperbolic stimuli with orthogonal axis, and iii) a pair of j_o target stimuli (12) and angular frequency type stimuli (13). Our main interest has been centered on testing the possibility that the visual system is organized to primarily process spatial information somewhat in terms of the latter pair. To that extent, we have been measuring the sensitivity of angular and radial frequency filters. We report the results on angular and radial frequency sensitivity elsewhere (14,15; Simas MLB, Frutuoso JT and Santos NA, unpublished data). Our use of the terms "channel" and "filter" refers to some sort of selective frequency processing supposedly undertaken by a given neuronal population.

In the present study we tested independence between the processing of radial frequency, i.e., a j_o target of 1 cycle per degree of visual angle (cpd), and either angular frequency stimuli or vertical sinusoidal gratings. We chose as radial frequency test stimulus a j_o target at 1 cpd for two reasons. First, because in our replication of the work of Kelly and Magnuski (16) we found maximum sensitivity occurring at 1 cpd for 6 of the 8 curves measured with 4 observers (MVG:2, JTF:2, SMM:2, and PCB:2, i.e., 2 curves per subject) (Simas MLB, Frutuoso JT and Santos NA, unpublished data); in the remaining two we observed maximum sensitivity at 2 cpd as reported by Kelly (17). Second, because those measurements use high contrast levels for the detection of j_o targets, a requirement compatible with the constraints of our equipment. Thus, we measured contrast threshold functions for a j_o target of 1 cpd in the presence of either angular frequency stimuli, BESANG, or sinusoidal gratings, BESSIN, for four optically corrected observers (JTF, FMV, SMM and PCB).

The patterns were generated in 256 gray levels on a Telefunken standard TV screen with interlaced RGB input and interfaced to a DT-2853 frame grabber controlled by an AT microcomputer. Both contrast and brightness were set digitally by the computer. All experiments were run at mean luminance of 2.4 fL (maximum and minimum luminances were 1.8 fL and 3.0 fL, respectively). Contrast was assumed to vary linearly with digital setting. A neutral gray board was used for fixation between trials. The two response functions for the radial frequency filter, j_o at 1 cpd, were obtained either with background angular frequencies of 1, 2, 3, 4, 6, 9, 13, 16, 24, 32, 47, 64, and 96 cycles per 360 degrees for BESANG, or with sinusoidal gratings of 0.2, 0.3, 0.5, 0.8, 1, 2, 3, 4, 5 ,6, 9 and 12 cpd for BESSIN, one at a time, superimposed or not (forced-choice) to a test stimulus (j_o at 1 cpd). All stimuli subtended 7.25 degrees of visual angle viewed from a distance of 1.50 m. The procedure involved two independent measurements of BESANG and BESSIN functions with at least 3 observers.

A total of 12 curves of either 13 or 12 points were measured in approximately 150 experimental sessions, i.e., six (JTF:2, PCB:2, SMM:2) for BESANG and six (JTF:2, PCB:1, SMM:2, FMV:1) for BESSIN. The order of stimulus presentation was randomized within each function given the constraint that the second measurement of a condition should always be made on a different day. The method used was the same as in Ref. 13. The background stimulus was either one of the angular frequencies or sinewave gratings listed above and the test stimulus was the sum of the given background stimulus and of the j_o at 1 cpd test stimulus. Only one background stimulus was used throughout a session. In each forced-choice trial sequence, one of two observation intervals (each lasting 2 s as opposed to 10 s in Ref. 13) randomly contained the background plus the j_o test stimulus while the other contained the background-only stimulus. The blank intervals between stimuli (ISI) and between trials (ITI) lasted 2 and 3 s, respectively. Following the presentation of the second stimulus, observers were required to identify the interval containing the composite stimulus. The computer would pause until an answer was entered and a beep would indicate a correct choice. The fixation point was viewed at the center of the stimulus and, to avoid possible brightness aftereffects during ITI, observers stared at a mark on the gray board while waiting for another beep indicating when to look at the screen. Observers were also told to restrain eye movements as much as possible during each 2-s stimulus presentation, all measurements being made binocularly. Contrast modulation of the background stimulus was constant at 42% regardless of whether it was shown alone or with the composite stimulus, but contrast of the filter-j_o target in the composite test stimulus could be varied in steps of 2/256, i.e., 0.8%, and had an initial setting of 8-11%. The criterion was three consecutive correct trials to decrease contrast by one step, and a single incorrect trial to increase it by one step. This criterion yielded a probability of seeing level equal to 0.5^3, or a frequency of seeing equivalent to 79% (18). In case either the upper or lower limits of contrast were reached (i.e., either 0.8% or 99%), the computer would repeat that contrast level again and again until the response of the subject reversed direction. Two to 4 conditions were run per day with each observer, always with a 10-15-min interval between conditions. A session lasted about 15-25 min. In each session either 5 or 10 maximum-minimum pairs were obtained and an average of 88.3 values were obtained for estimating each point of BESSIN, whereas an average of 99.7 values were obtained for BESANG.

Figure 1 shows examples of pairs of stimuli applied to obtain the two functions. On the top is a pair used to measure BESANG and at the center and on the bottom are pairs used to obtain estimates for BESSIN. On the left are only the background stimuli and on the right the background plus the test stimulus. Thus, for BESANG we show the pair used to obtain the estimate at 4 cycles (top left). On top right we can see 4 cycles plus j_o at 1 cpd. For BESSIN we show two pairs, one at 1 cpd (center) and another at 2 cpd (bottom). Thus, sinewave gratings of 1 and 2 cpd are presented at center and bottom left, respectively, while the same frequencies added to the 1 cpd j_o target are shown on the right (center and bottom). The points illustrated in this figure are points where inhibition was observed.

Figure 2 shows grandmean contrast thresholds for the j_o target at 1 cpd as a function of either background angular frequency or vertical sinusoidal gratings. Contrast was defined as in Ref. 13. Grandmeans were obtained from the averages across subjects for each individual point of the two functions. The absolute threshold for j_o at 1 cpd (i.e., baseline contrast) is represented by a dashed line at its level, i.e., 0.061 or 6.1%.

In BESANG we observed that most of the points fell above the baseline contrast showing inhibitory effects as large as those observed for angular frequency filters with the same equipment (14,15). Note the existence of a plateau of maximum inhibition around 3-24 cycles. Most of the points are 25% above threshold for the j_o target, i.e., are higher than 0.076, showing selectivity and widespread inhibition. In the 9-24 interval it almost reaches 50% above the j_o target threshold. It is interesting to note independence around 1-2 cycles.

On the other hand, BESSIN shows selec-

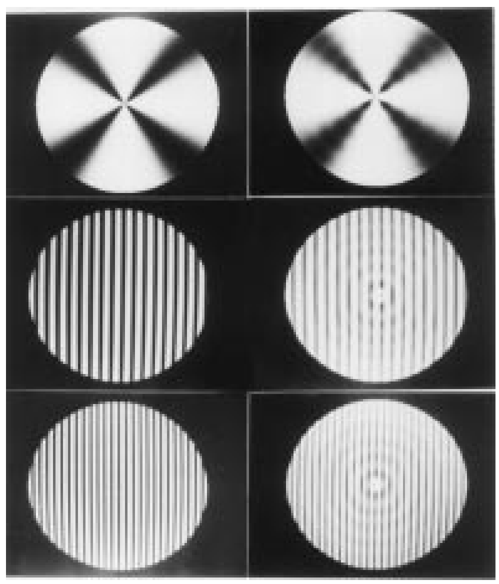

Figure 1 - Examples of pairs of stimuli applied to obtain the two functions. On the top is a pair used to measure BESANG and at the center and on the bottom are pairs used to obtain estimates for BESSIN. On the left are only the background stimuli and on the right the background plus the test stimulus. Thus, for BESANG we show the pair used to obtain the estimate in 4 cycles (top left). On the top right we can see 4 cycles plus J_o at 1 cpd. For BESSIN we show two pairs, one at 1 cpd (center) and the other at 2 cpd (bottom). Sinewave gratings of 1 and 2 cpd are presented at center and bottom left, respectively, while these same frequencies added to the 1 cpd j_o target are shown on the right (center and bottom). The points illustrated in this figure are points where inhibition was observed.

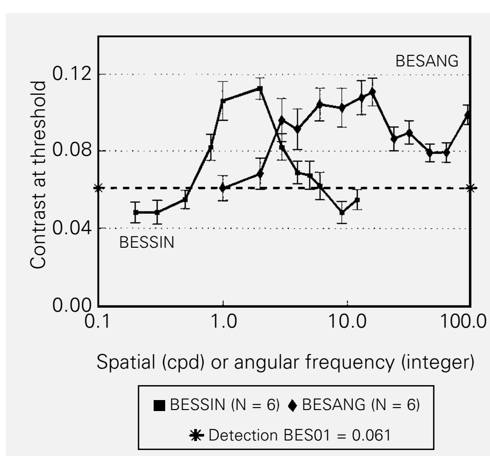

Figure 2 - Grandmean contrast thresholds for the j_o target at 1 cpd as a function of either background angular frequency, i.e., BESANG, or vertical sinusoidal gratings, i.e., BESSIN. Grandmeans were obtained from the averages across subjects for each individual point of the two functions. The absolute threshold for j_o at 1 cpd (i.e., baseline contrast) is represented by a dashed line at its level, i.e., 0.061 (6.1%). Error bars of the mean are corrected at the 99% level of confidence by the Student *t*-test. Please note that the angular frequencies are adimensional and integers. See text for further details.

tive inhibition, selective summation, and independence. Selective inhibition is shown in the range of 0.8-3.0 cpd, all 25% above the j_o target threshold. The points at 0.2-0.3 and 9-12 cpd show summation effects, i.e., are values 25% below the j_o target threshold. Points at 0.5 and 5.0-6.0 show close to independence values, i.e., values equivalent to that found for the absolute threshold of j_o target.

The concepts of summation, inhibition and independence are discussed elsewhere (14). In brief, these refer to assumptions that can be made about filter or channel properties. When summation exists, dependence between channels is generally assumed and inference about a single mechanism is made. If values crowd around the reference threshold, then independence is assumed. However, if there is inhibition, interpretations are more complex. We interpret inhibition as interdependence or interaction between filters or channels, indicating that in this situation the composed stimulus is activating two or more channels simultaneously and that one prevails over the others, possibly indicating some sort of priority processing. This interpretation deals with the fact that, since the receptor population of the retina is limited, there will necessarily be some sort of interdependence between the various processes taking place within a shared neuronal network in visual system processing. Our results show a quite specific interaction between sinewave gratings and j_o targets, as expected, based on the results reported by Kelly (12,16). Also, it is interesting to observe a more extended interdependence for BESANG rather than for BESSIN which may support application of Hankel series defined in polar coordinates (13,19) that couple j_n targets to n angular frequency. Thus, for j_n where n = 0, we found that angular frequencies of n>2 may inhibit detection of j_o modulated radial frequency at its maximum sensitivity range, i.e., 1 cpd. Careful electrophysiological work is required to better understand these complex interactions.

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