Strength of feature contrast mediates interaction among feature domains

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Received 1 April 2003; revised 26 July 2003; accepted 8 August 2003

Abstract—Traditional theories of texture segregation suggest that elementary visual features are processed in parallel by independent modules at early visual stages. Here we show that, for small feature contrasts and large values evoking perceptual popout, different forms of module interaction exist. While discrimination of highly salient features rests on independent feature specific pathways, information is summed across domains when barely noticeable ones are to be detected in homogeneous textures.

Keywords: Feature contrast; feature synergy; nonlinear summation; Weber fraction.

1. INTRODUCTION

When we search a visual scenery we are guided by locations of feature dissimilarity which help to separate objects from their surround. Feature contrast, defined as the difference of object and surround within a basic visual feature such as color, form, orientation or direction of motion, is a major determinant of saliency. Objects with high contrast in at least one feature ‘pop out’ of the scene and are easily and effortlessly detected, while weakly contrasted objects are nonsalient and require serial scanning to be found (Treisman and Gelade, 1980; Treisman, 1988; Treisman and Sato, 1990; Wolfe et al., 1989; Nothdurft, 1991, 1992, 1993, 2000; Wolfe, 1994).

A question which raised much theoretical and empirical interest is how feature contrasts from different dimensions are combined to result in the overall object saliency. While ‘traditional’ theories claim that elementary visual features are handled by independent modules at the level of early vision (Treisman and Gelade, 1980; Treisman, 1988; Landy and Bergen, 1991), the rigorous ‘channel view’ of early visual processing has become questionable in the light of recent findings (see

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Wilson and Wilkinson, 1997, for overview). Since the role of lateral interconnections between nearby but nonoverlapping elementary feature detectors for cross-domain interactions has been shown with electrophysiological (Polat et al., 1998) and psychophysical methods (Polat and Sagi, 1993, 1994), independence is viewed as a special case and processes of inhibition and synergy among different feature domains are postulated (Tononi et al., 1992; Gilbert et al., 1996; Phillips and Singer, 1997).

But, empirically, the experimental conditions for cross-domain interaction and independence are no clear matter. Various psychophysical studies report improvement in detection, discrimination or search performance when two ore more features coincide at one location (Beck, 1967; Callaghan, 1984; Farell, 1984; Caelli and Moraglia, 1985; Callaghan et al., 1986; Callaghan, 1989; Nothdurft, 1993, 2000; Abele and Fahle, 1995; Rivest and Cavanagh, 1996; Kubovy et al., 1999; Kubovy and Cohen, 2001). But only in some of these was the independence assumption explicitly tested (Caelli and Moraglia, 1985; Abele and Fahle, 1995; Kubovy et al., 1999). Moreover, there are also studies which report no or minor improvement with multiple coincident cues (Pashler, 1988; Gray and Regan, 1997), sometimes even contrary to the authors’ theoretical reasoning (Phillips and Craven, 2000; Phillips, 2001). This indicates that the experimental side conditions of the visual task and the particular selection of features are crucial for the resulting scheme of summation.

Scarcely noticed so far in this debate is the role of the feature contrast strength, commonly held constant at an arbitrary value in experiments. In view of the fact that the strength of feature contrast determines the mechanism of visual search, one may expect different forms of feature module interaction when a barely noticeable target is to be detected compared to the case where two already highly salient targets are to be discriminated. While summation among feature domains facilitates detection of small feature contrasts, comparison along single independent feature dimensions is effective for segregation of highly salient targets, as assumed in classical models (Treisman and Gelade, 1980; Sagi and Julesz, 1985; Landy and Bergen, 1991; Sagi, 1995; Phillips and Craven, 2000).

In this study we show that the strength of feature contrast mediates the degree of summation among feature domains. We show that detection performance for barely noticeable feature conjunctions is much better than predicted from the independence assumption. In contrast, facilitation is shown to be not stronger than expected from independent processing of different features when subjects discriminate highly salient stimuli that strongly differ from the surround in two feature dimensions simultaneously.

2. MATERIALS AND METHODS

2.1. Subjects

Nineteen undergraduate students were recruited as subjects: 11 were female, 8 male. All subjects had normal or corrected-to-normal vision, no former psychophysical