Bioengineering Conference, 1996, Proceedings of the 1996 IEEE Twenty-Second Annual Northeast

Two Neural Pathways for Fourier and non-Fourier Motion

T.V. Papathomas*, J.W. McGowan**, C. Chubb**, and A. Gorea‡
* Department of Biomedical Engineering, ** Department of Psychology, Rutgers University
‡ Laboratoire de Psychologie Expérimentale, CNRS & Université René Descartes, Paris, France

ABSTRACT

Humans can perceive non-Fourier visual motion, i.e., motion that contains no coherent structure in the distribution of stimulus energy in the spatiotemporal frequency domain. The question that still remains unanswered is whether this non-Fourier motion is analyzed by a separate neural pathway or whether there is a unique pathway that is responsible for both Fourier and non-Fourier motion analysis. We present experimental evidence that strongly supports the separate-pathway hypothesis, and we suggest a possible computational model that can account for the data.

INTRODUCTION

Fourier (1st-order) motion models can extract luminance-based motion, which contains energy in preferred directions in the frequency domain. Fourier models cannot extract motion from stimuli which do not contain such energy [Chubb & Sperling 1989], but humans can. This led researchers to hypothesize non-Fourier (2nd-order) motion mechanisms in the human visual system, in addition to the 1st-order ones. O'Keefe et al. [1993] used 2nd-order stimuli to study the properties of putative non-Fourier mechanisms. The existence of separate systems has been challenged recently by an alternative hypothesis [i.e., Johnston and Clifford 1995], which proposes a single motion system that could account for both Fourier and non-Fourier motion. The purpose of the present study was to test this hypothesis, and to examine systematically the properties of the Fourier and non-Fourier motion systems.

METHODS

To test the hypothesis of a single motion system, we conducted psychophysical experiments using two types of elements against a background with uniform luminance L0 (see Fig. 1). The first type of element, "L", has a uniform luminance L, and it is distinguished from the background only by virtue of its luminance difference L-L0. The other element, "C", is distinguished from the background only by virtue of its local contrast, because its mean luminance is equal to that of the background, L0; it is composed of a random distribution of bright and dim dots of equal densities, with luminances La and Lb, above and below L0, respectively, resulting in a nonzero contrast C. It is necessary for the texture patch "C" to have a mean luminance, Lc, equal to L0, so as not to excite the putative Fourier motion system, and to excite only the front-end filters of the putative non-Fourier motion system. This was achieved by using a new accurate and efficient technique for obtaining texture patches of a desired mean luminance [Papathomas, Gorea & Chubb 1996].

Supported by grant 94-30 from the McDonnell Foundation

0-7803-3204-0/96$05.00©1996IEEE

We used two types of configurations, in which the elements were arranged in space-time to produce two distinct stimuli, each involving two competing motion paths of opposite directions: a "homogeneous" path and a "heterogeneous" one. **Stimulus 1:** Homogenous path: L-L; heterogeneous path: L-C (Fig 1A). **Stimulus 2:** Homogenous path: C-C; heterogeneous path: L-C (Fig 1B).

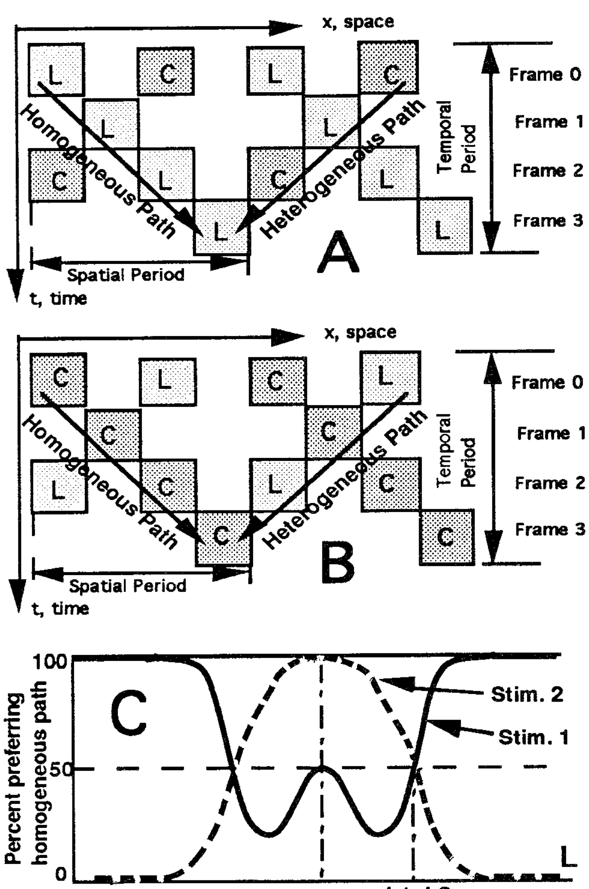

Fig 1. A: Stimulus 1 (LL vs LC); **B:** Stimulus 2 (CC vs LC); C: Predictions for a single-system hypothesis

The observer's task was to report the direction of motion in a two-alternative forced-choice paradigm. We varied the value of L, and we kept C fixed. We recorded the percentage of trials in which the observer favored the direction of the homogeneous path, as a function of L. We then estimated the value of L for which motion is ambiguous; call this value **L1** for stimulus 1, and **L2** for stimulus 2. The single-motion system hypothesis predicts that L1=L2, i.e. it must obey the principle of "transition invariance" [Werkhoven, Sperling &