

Eye Movement Pre-Algebra and Visual Semantic Algebra: Possible Links Within Denotational Mathematics Framework and Husserlian Phenomenological Theory

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ABSTRACT

This article proposes a new denotational mathematics entity, i.e., the eye movement pre-algebra (EMpA), which may be considered as a pre-algebraic structure in a certain sense generating, according to universal algebra, Husserlian phenomenological theory and structuralism, another basic algebraic structure of denotational mathematics, said to be visual semantic algebra (VSA).

KEYWORDS

Algebra, Denotational Mathematics, Eye Movements, Husserl's Phenomenology, Structuralism, Visual-Spatial Skills

1. INTRODUCTION

Basically, human visual function, the chief one among the physiological functions of human perception, has four main abilities: fixing eyes upon an object; pursuing a moving object; responding to a stimulus which appears in the external neighbourhood of visual field, through a movement of eyes toward the direction along which such a stimulus manifests; exploring visually environmental space in searching of objects and their details. These basic four skills spring out from the general cognitive capability of visual-spatial attention (VSA_t), one of the most important cognitive function of human psyche. Neurophysiology has showed that VSA_t always precedes any next eye movement, that is to say, the former implicitly guides and directs the latter in its explicit action of orientation, predisposing the related visual field, so influencing and conditioning many other higher cognitive functions (like memory, voluntary judgement, etc.) (Facoetti, 2004).

Human eye movements are classified into two main types, namely, fixations and saccades, respectively when eyes stop in a certain position, and when they suddenly and fastly move towards another position. The resulting sequence of fixations and saccades, is called a scanpath. A smooth pursuit refers instead to eyes slowly following an object in movement. The set of fixational eye movements includes the so-called microsaccades, which are nothing but small, involuntary (i.e., unconscious) saccades that occur during attempted fixation of an object. From much time, it has

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been deemed that most information by eyes come mainly from fixations or smooth pursuits, but not by saccades. Instead, recent neurophysiology research has shown what primary role play saccades, included microsaccades, for the general visual perception (Martinez-Conde et al. 2006).

In any case, the class of eye movements comprehends the following ones: saccades, smooth pursuit movements, vergence movements, and vestibulo-ocular movements, which will be briefly described, in their physiological essence, in the next section. Now, from a mathematical viewpoint, in this note, just we would like to consider a possible mathematical structure of universal algebra, that we shall call eye movement pre-algebra (in short, EMpA), formalizing these eye movements, in such a way to be closely related to another formal structure belonging to Yingxu Wang's denotational mathematics framework, called visual semantic algebra (in short, VSA), through a suitable conceptual bridge casted by Husserlian phenomenology.

2. TYPES OF EYE MOVEMENTS AND THEIR FUNCTIONS: A BRIEF SURVEY

Human beings are epi-ontogenetically prepared, since their childbirth, to develop eye movements, in particular saccades. To be more precise, there are four basic types of human eye movements, i.e., saccades, smooth pursuit movements, vergence movements, and vestibulo-ocular movements. The functions of each type of eye movement are briefly introduced herein, closely following (Harris & Butterworth, 2004; Purves et al., 2001).

Saccades (in short, S) are rapid, ballistic movements of the eyes that abruptly change the point of fixation. They range in amplitude from the small movements, made while reading for example, to much larger movements, made while gazing around a room for example. Saccades can be elicited voluntarily, but they also occur reflexively whenever the eyes are open, even when are fixed on a target. For instance, the rapid eye movements that occur during an important phase of sleep are also saccades. After the onset of a target for a saccade (as, for example, the stimulus in the case of the movement of an already fixated target), it takes about 200 ms for eye movement to begin. During this delay, the position of the target with respect to the fovea is computed (that is, how far the eye has to move), and the difference between the initial and intended position, or "motor error", is converted into a motor command that activates the extraocular muscles to move the eyes the correct distance in the appropriate direction.

Saccadic eye movements are said to be "ballistic" because the saccade-generating system cannot respond to subsequent changes in the position of the target during the course of the eye movement. If the target moves again during this time (which has the order of about 15-100 ms), the saccade will miss the target, and a second saccade must be made to correct the error. Saccades can also be voluntary, but are mainly made unconsciously.

Smooth pursuit movements (in short, SPM) are much slower tracking movements of the eyes designed to keep a moving stimulus on the fovea. Such movements are under voluntary control in the sense that the observer can choose whether or not to track a moving stimulus. Surprisingly, however, only highly trained observers can make a smooth pursuit movement in the absence of a moving target. Most people who try to move their eyes in a smooth fashion without a moving target simply make a saccade.

The smooth pursuit system can be tested by placing a subject inside a rotating cylinder with vertical stripes. In practice, the subject is more often seated in front of a screen on which a series of horizontally moving vertical bars is presented to conduct this "optokinetic test". The eyes automatically follow a stripe until they reach the end of their excursion. There is then a quick saccade in the direction opposite to the movement, followed once again by smooth pursuit of a stripe. This alternating slow and fast movement of the eyes in response to such stimuli is called *optokinetic nystagmus*. Optokinetic nystagmus is a normal reflexive response of the eyes in response to large-scale movements of the visual scene and should not be confused with the *pathological nystagmus* that can result from certain kinds of brain injury (for example, damage to the vestibular system or the cerebellum).

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