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Foveal versus parafoveal scanpaths of visual imagery in virtual hemianopic subjects

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Abstract

Sophisticated string analysis [compressed regional string analysis, cRSE] shows significant differences following therapeutical masking of the foveal region during a virtual hemianopia. The visual imagery scanpath is done over a compressed mental image that needs longer fixation duration but fewer saccades than the real image. Combination of different viewing tasks with types of pictures permits to show how scanpath top-down strategies can be enforced or decreased by proper combination of task and picture; this is influenced by the mask of fovea versus no-mask of fovea difference, with bottom up mechanisms becoming more important with loss of foveal viewing strategies in the mask condition.

Keywords: Scanpath eye movements; Visual imagery; Virtual hemiblindness; String editing; Markov analysis; Abstract versus realistic pictures

1. Introduction

Several methods to analyse the eye scanpath [1–9] have been tested in the past (see Fig. 1). Besides the standard analysis like calculation of fixation durations, number of saccades in certain regions of the picture and the global-local ratio of scanpath saccades [3], there are statistical, more regionally weighting methods as the *Markov analysis* (MA) [6–9] of zero and first order; and methods of *string editing* (SE) primarily used in linguistics and genetics, that have been introduced by Stark and others: Stark et al. [2,5,7,8], Zangemeister et al. [3,4] since the early nineties into the field of scanpath analysis(see Fig. 2).

We have used and compared regional *SE* (RSE) and compressed RSE (cRSE) where direct repetitions of string-contents are deleted. Further, we have developed a vectorial representation of scanpath strings, Vector SE [VSE], and the weighted VSE [wVSE], where the string vector is weighted according to the frequency of occurrence of similar directions within strings. This latter method has the advantage of working independently of the setting of *a priori* (geometrical) *regions of interest* (ROIs) or *a posteriori* (intelligent, depending on picture content) ROIs (Fig. 3). In the case that ROIs are used, it is obvious that an a priori setting of ROIs favours the analysis of *bottom up* (BU) behavior, and a posteriori setting a *top down* (TD) behavior of the scanpath string.

1.1. Visual field defects

Patients that are blind on one half of their visual field i.e. hemianopic [10–17], usually due to occipital stroke or tumor, show specific oculomotor adaptations due to spontaneous and therapeutic changes that have been reported over the years [14,18,19]. Using specific training regimes, they may be able to adapt and circumvent this half-field blindness, and may also show specific changes in their visual imageries [20–27]. Using a previously [28–31] described computer simulation of such a visual field defect on a visual display terminal (VDT) we posed the question:

Is it possible to enhance and record the effect of this adaptation through "training" of healthy subjects with a virtual hemianopia by enlargement of the 50% horizontal field defect towards the "healthy" seeing side (SHF) by +5°, in analogy to the "forced used therapy" developed by Taub et al. [34] in hemiparetic patients where patients were forced to use only their paretic limb?

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2. Methods

Comparing the different analytical options we decided to use the cRSE for analysis of our recordings in 20 normal subjects experiencing a complete dense 50% virtual homonymous hemianopia–with 10 of them undergoing an additional training of 10 min with enforced virtual hemianopia of 55%, whereas the other 10 underwent a sham training of the same duration. The technique of inducing virtual hemianopia has been described by us before [28–31]. In short, it consists of an IR-reflection eye movement monitor (0.1° resolution; overall bandwidth 0–250 Hz) that has an active link to the 23” screen that is viewed by the subject and where a dark grey blinding of 50% or 55%, respectively, of the viewed image occurs directly related to the eye movements (overall latency of the generation of the mask 8 msec).

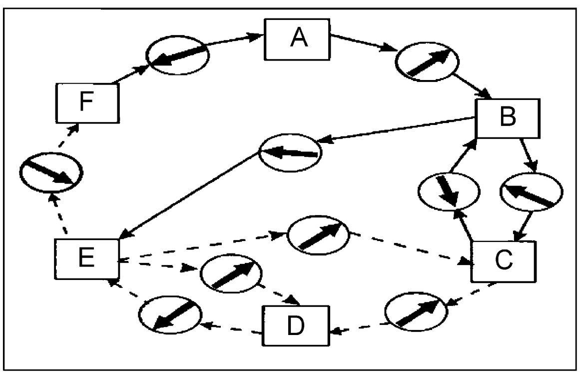

Fig. 1. Scanpath theory: Eye fixations shown as connected sequence resulting in a sequential string of visited regions of interest (ROIs) (lettered squares) and saccadic eye movements (circles with arrows) shown by solid arrows form the “feature ring” of the scanpath theory in the non-iconic model of this example. The variability of ROI-sequences is represented by the dashed arrows.

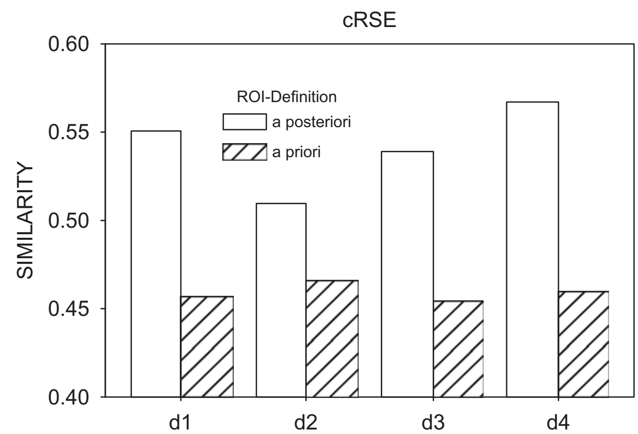

Fig. 4. Similarity as a function of ROI definition and set. Highly significant differences of the ROI definition by regional SE. *A posteriori* differentiates better than *a priori*.

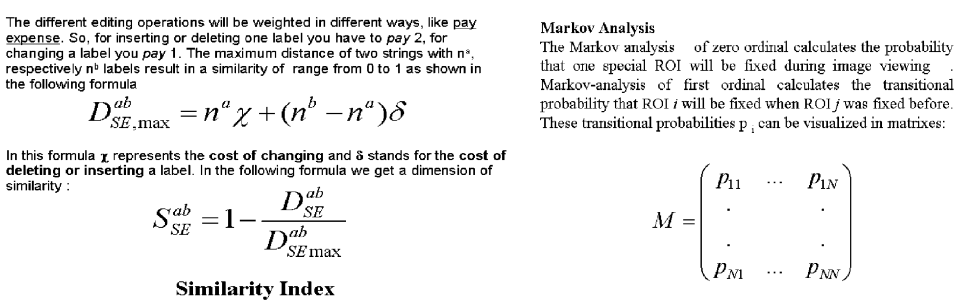

Fig. 2. String editing (SE) (left) and Markov analysis (MA) (right) algorithms used; SE: definition of similarity index; MA: the Markov analysis of zero ordinal calculates the probability that one special ROI will be fixated during image viewing. MA of first ordinal calculates the transitional probability that ROI *i* will be fixated when ROI *j* was fixated before. These transitional probabilities *p* sub *i* can be visualized in matrices.

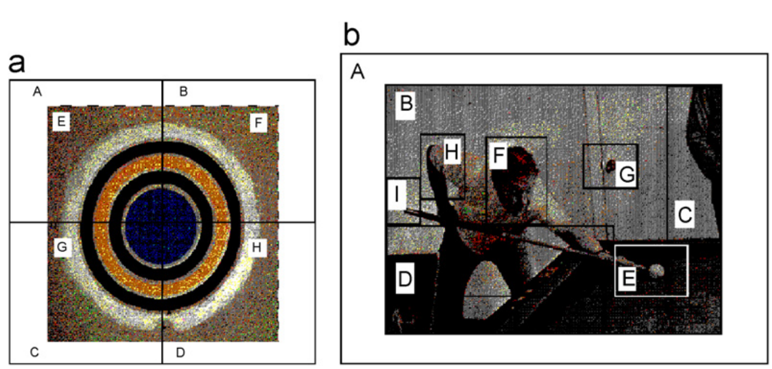

Fig. 3. A priori and a posteriori analysis: (a, left) Geometric *a priori* definition, “Spring Cool” by Ken Noland, 1962; (b, right) Semantic *a posteriori* POI definition, “Deadeye” by Lane Terry, 1971.