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Arbitrary Eye Movement Strategies in Global-Local Processing Experiments

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Abstract

Perceptual organization is one of the most hotly debated issues in visual perception. Human adults, in normal conditions, process global features faster than local details, the effect that is called "Global Precedence". Researches have shown that as stimulus eccentricity gets more distant from the fovea, the perceptual decisions of local details become more delayed. This even happens when the gaze is fixated on the center of the field of view and the stimulus location is manually adjusted. The present study aims to explore the eye movement strategies in the process of global and local features, when the gaze point is not restricted to a particular fixation point. Fourteen participants were asked to respond to Matching and Similarity Judgment tasks. The data was recorded using EYELINKII™, with a sampling frequency of 1000Hz. The Global Precedence Effect (GPE) was observed in the two tasks. Additionally, a higher average of "arbitrary eccentricity" in global trials was observed as compared to local trials. Arbitrary eccentricity was referred to as the eccentricity individuals unconsciously choose to perceive the stimuli. Furthermore, the number of fixations were significantly greater in local trials. From our findings we speculate that in daily life we can perceive the world globally with peripheral vision and not always need eye-movements and only decide to focus foveally when selectively attending to local details seems necessary.

Keywords: Eye movement strategy, Global precedence, Global-Local processing, Visual perception.

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1. Introduction

The global precedence effect in global-local visual perception, as introduced by Navon [1], refers to the condition that global aspects of a scene are processed more rapidly than local details. This perceptual dynamic is influenced by many factors that can be divided into two major categories: subjective or internal factors, e.g. age, disorder, culture, and external factors that called perceptual field variables (PFVs); e.g. stimulus size, sparsity, and eccentricity. A recent systematic review and meta-analysis via a standard PRISMA framework explored the research articles from 1982 to 2019 and showed that 'Eccentricity' besides 'Congruency' and 'Visual size', is an important PFV for the global precedence effect [2].

Controlling the above mentioned factors, in [3], Navon and Norman asked whether global features located at a given eccentricity are processed faster than local features located at the same eccentricity, and their results indicated that the global level was detected faster than the local level when eccentricity was controlled. Also, to investigate the effect of eccentricity researchers examined global precedence effects at different eccentricities using Navon compound stimiuli. In these experiments eye-movements were eliminated by instructing subjects to fixate at the center fo the screen and observe the stimulus using their peripheral vision [4, 5]. However, it has been argued that the projecting to the peripheral part of the visual field may have led to a poor resolution in percieving local details than global structures [6-8] because peripheral vision has a lower acuity.

To better undrestanding about given strategies during free eye movements in global-local visual perception, we need to address the following questions: How much eye movement scanning is used and needed to percieve global and local features when we can move our eyes freely and gaze everywhere that we can? Are the eye movements similar when the perception goal is to process global structures or todetect local details? What is the gaze strategy to when the gaze point was not restricted to a particular fixation point in local-global Navon Tasks? To answer these questions, we designed two experiments based on the Navon Task employing two different paradigms: 1) Matching Judgment and 2) Similarity Judgment. The experiments were designed in a way that individuals could freely move their eyes and eye tracking was recorded with a highly accurate binocular eyetracker setup (EYELINKII™).

2. Method Experiment 1

Stimuli and experimental paradigm

Fourteen participants were attended in this experiment. All participants are from young students of Radboud University of Nijmegen in Netherlands (age 25.38 $\pm$3.4, 6 females and 8 males). According to ethical guidelines, all participants filled and signed the form to confirm allowing to use the information and recording data only in research projects. All participants were individually engaged in the task in a quiet and darkened room. Participant's chin rested on a chin rest located 60 cm away from the display screen (pixel resolution 1024 by 768, 16-bit color, 100 Hz refresh rate). They were presented with a divided Navon task with one simple and one Navon Hierarchical stimulus (Figure 1) and were instructed to indicate whether the stimulus in the predefined target level (global or local) of the hierarchical shape

was similar to the simple stimulus, by pressing one of two keyboard buttons. Simple and complex stimuli were randomly situated on the right or left of the screen. Participants were encouraged to respond as fast and as accurately as possible. The experiment consisted of two blocks (local block and global block) of 120 trials. The inter-block-interval was approximately 5 minutes for resting and cancelling priming effects.

In each trial a target stimulus was presented after a cross fixation. Blocks were presented in a counterbalanced order. So, half of the participants started with the block with a target in the local level and then completed the block with the global target. The other half of the participants started with the block target in the global level and then completed the block with target in local level (global trials). In the local block subjects were instructed to compare the simple shape and local level of the Navon Hierarchical stimuli and ignore the global level, while in the global block subject instructed to only focus on the global level discarding the other level (local trials).

After the instruction, all participants practiced a sample block of 6 trials before commencing with the blocks of test trials. At the beginning of each trial, an 800 milliseconds fixation cross (0.05') was followed by the appearance of the test stimulus. The stimulus remained on the screen for a maximum of 3000 ms. Then a blank page was presented for 200 ms. No feedback was provided. Stimuli were presented and responses were recorded within the Psychtoolbox and Matlab (2017b) environment.

Each stimulus consists of one simple shape, a circle or a square in the left or right of the screen for matching-- that is to be considered as the reference -- and one Navon Hierarchical stimulus on the opposite side. The Navon Hierarchical stimuli were either large circles made up of small circles or squares, or large squares made up of small circles or squares, as shown in Figure1. The small elements were 12 pieces evenly distributed in the perimeter of the large shape.

Data analysis

For statistical analysis we employed scripts using the statistical toolbox MatLab2017. Arbitrary eccentricity was calculated for each trial, which was defined as the minimum eccentricity from the all targets that subjects had shown during a total trial and could be computed via formula (1). T refers to set of targets and F regards set of fixations in that trial. For computing arbitrary eccentricity, eye-tracking data was preprocessed. After saccade and fixation extraction, eccentricity of every fixation was computed by measuring the distance of the fixation point's coordinates with every target figures position (x_t , y_t) in each trials in visual angle that can be computed using formula (2).

$$Ecc_{Arbitrary} = \min_{\forall f \in F; t \in T} (Ecc_{ft}), \quad (1)$$

$$Ecc_{ft} = \sqrt{(x_{ft} - x_t)^2 + (y_{ft} - y_t)^2}, \quad (2)$$

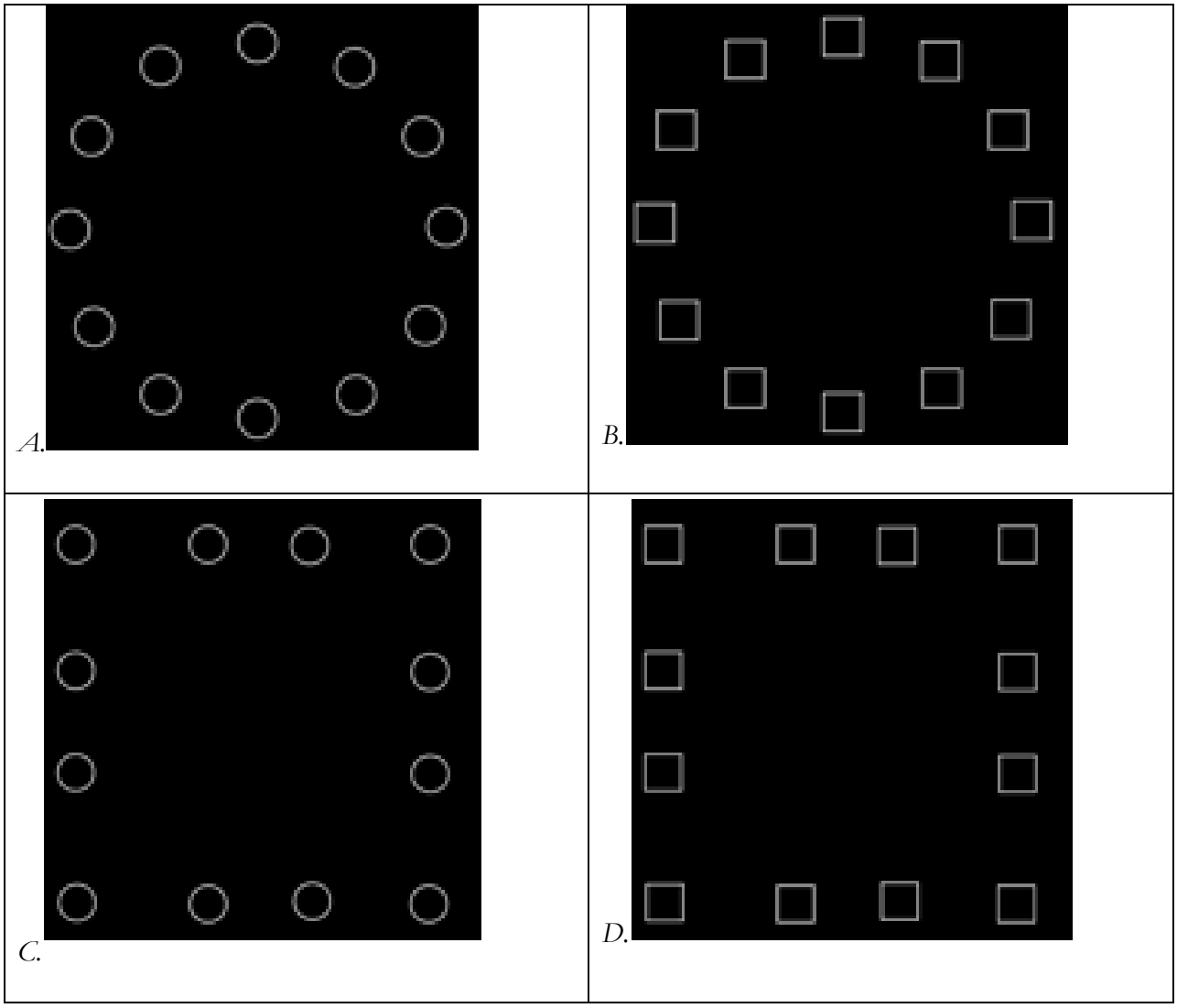
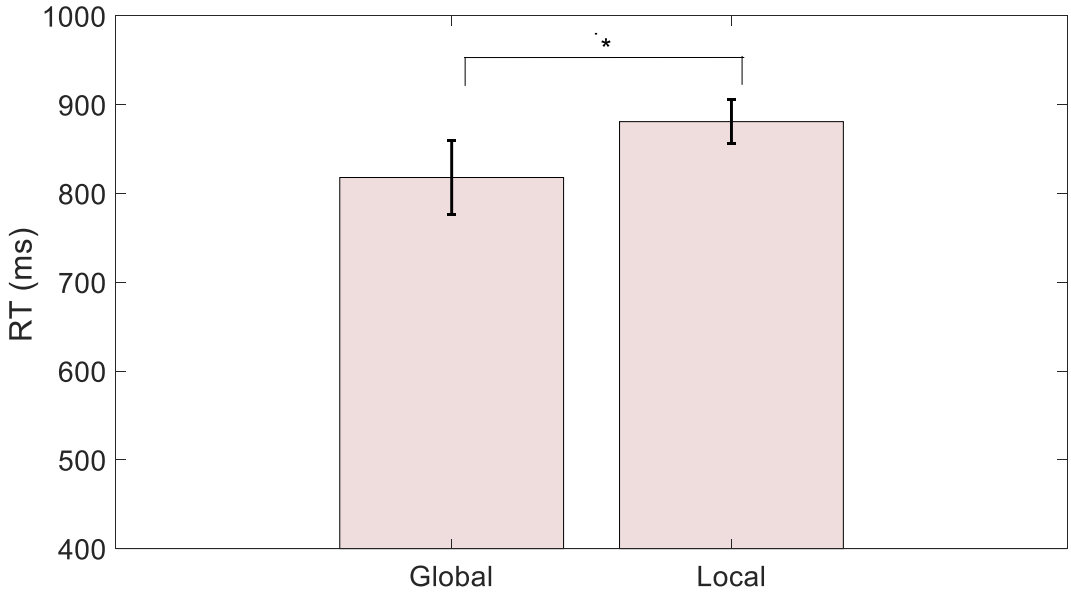


Figure 1. The set of stimuli used in the Experiments 1 and 2.

Results Experiment 1

Results from this task show the expected global precedence effect. Participants responded significantly faster (average 63 ms) to the global trials than to the local trials (Figure 2A). Moreover, an interference effect between levels can be observed in one direction from global information to local information (Figure 2B). There is no significant difference between congruent and incongruent trials for the global conditions, but there is a statistically significant difference (average 56 ms) between congruent and incongruent trials in the local processing condition.

a.



b.

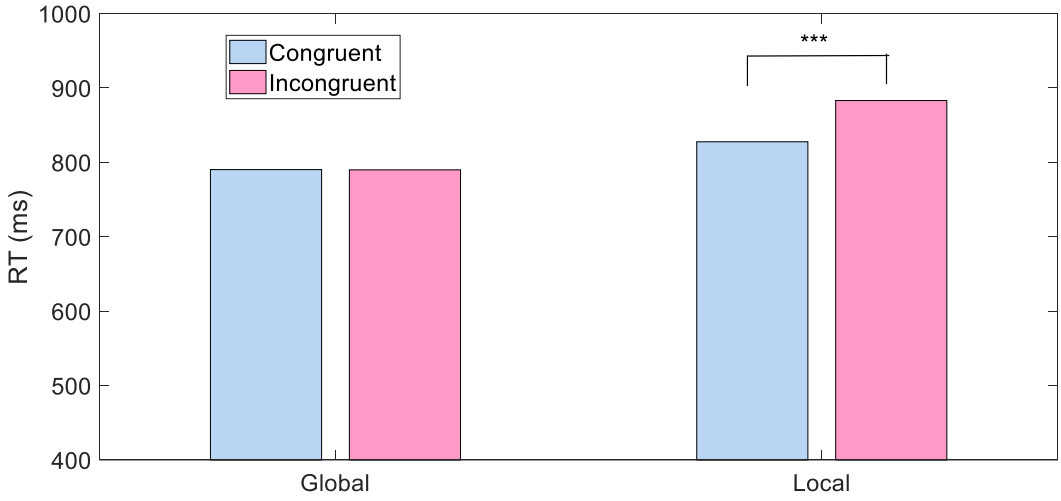
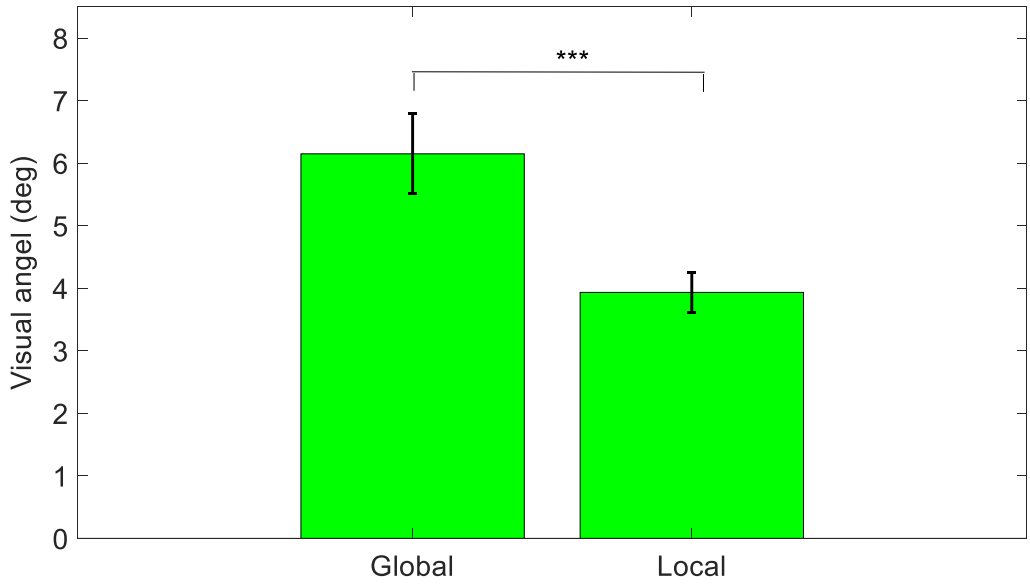


Figure 2. (a) Precedence effect: Average reaction time in global vs local trials in experiment1. (b) Interference effect: Average reaction time by different congruency.

Dependent t-test shows that participants' arbitrary eccentricity in the global processing condition is

higher compared to the local processing condition (Figure 3A), meaning that a visual angle of about 6 and 4 degrees are sufficient for global processing and local processing, respectively. Figure 3B illustrates that participants employ less fixations in global processing conditions as compared to local processing conditions. Statistical results are summarized in Table1.

a.



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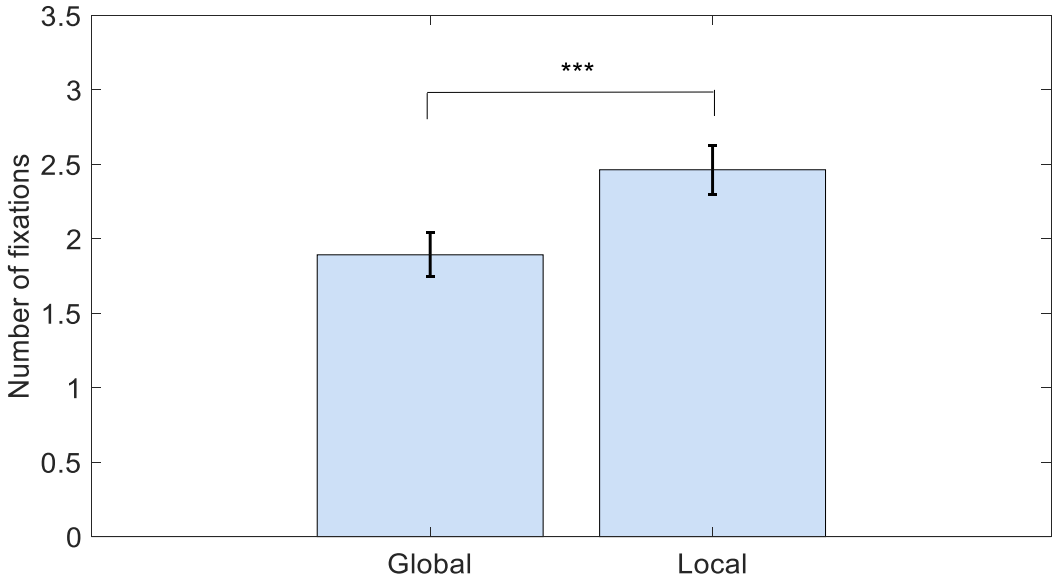


Figure 3. (a) Average arbitrary eccentricity in global vs local trials in experiment 1. (b) Average number of fixations in global vs local trials.

Table 1. Descriptive statistics and paired t-test results for experiment 1

		Descriptive Statistics		Paired T-test Statistics		
		M	SD	df	t	P-Value
RT in	global trials	817.98	157.72	13	-1.89	0.04
	local trials	880.91	93.05			
RT in	global congruent trials	810.31	154.59	13	0.03	0.97
	global incongruent trials	809.96	160.76			
RT in	local congruent trials	827.70	94.10	13	5.28	7.38e-05
	local incongruent trials	883.13	98.97			
Arbitrary Eccentricity in	global trials	6.15	2.38	13	4.37	7.54e-04
	local trials	3.93	1.20			
Number of Fixations in	global trials	1.89	0.55	13	-4.07	0.001
	local trials	2.46	0.61			

3. Methods Experiment 2

Stimuli and experimental paradigm

All participants are similar to experiment 1. As in Experiment 1, all participants individually took the tasks in a quiet and darkened room. Participant's chin rested on a chin rest, 60 cm away from the monitor screen (pixel resolution 1024 by 768, 16-bit color, 100 Hz refresh rate). After a cross fixation, they were presented with a divided Navon task with two Navon Hierarchical stimuli and were instructed to indicate whether in the predefined target level (global or local) the two shapes are similar at that level or not. Responses were recorded by keypress. Participants were encouraged to respond as fast and accurately as possible. The experiment consisted of two blocks, local and global, of 240 trials, over all.

After the instruction, all participants completed a practice block with 6 trials before commencing with each block of test trials. At the start of each trial, 800 milliseconds fixation cross (0.05') was followed by the appearance of the test stimulus. The stimulus remained on the screen until the participants had responded or three seconds finished. Then a blank page was presented for 200 milliseconds. No feedback was provided. Stimuli were presented and the responses were recorded using the Psychtoolbox and Matlab (2017b) environment.

Stimulus patterns were automatically generated by manual code written using computer vision system toolbox, Matlab 2017. Each stimulus consists of two Navon hierarchical stimuli. The hierarchical stimuli were either large circles made up of small circles or squares or large squares made up of small circles or squares, as shown in Figure1. There were 12 small elements in the parameter of large shapes that situated in the uniform distance from each other.

Data Analysis

Data analysis including, statistical analysis and Arbitrary eccentricity calculations, was done as same as Experiment 1.

Experiment 2: Results and discussion

Results from the similarity judgment task of experiment 2 shows a significant global precedence effect which means that subjects responded faster (average 183 ms) to global trials compared to local trials (Figure 4A). In addition, the interference effect between levels can be observed bi-directionally. In other words, both the global to local interference effect and the local to global interference effect are significant(Figure 4B).

Dependent t-test revealed that the participants' arbitrary eccentricity in global conditions is higher compared to local conditions (Figure5A). As Figure5B shows, participants had less fixations in global conditions in comparison with local conditions. Statistical results are summarized in Table2.

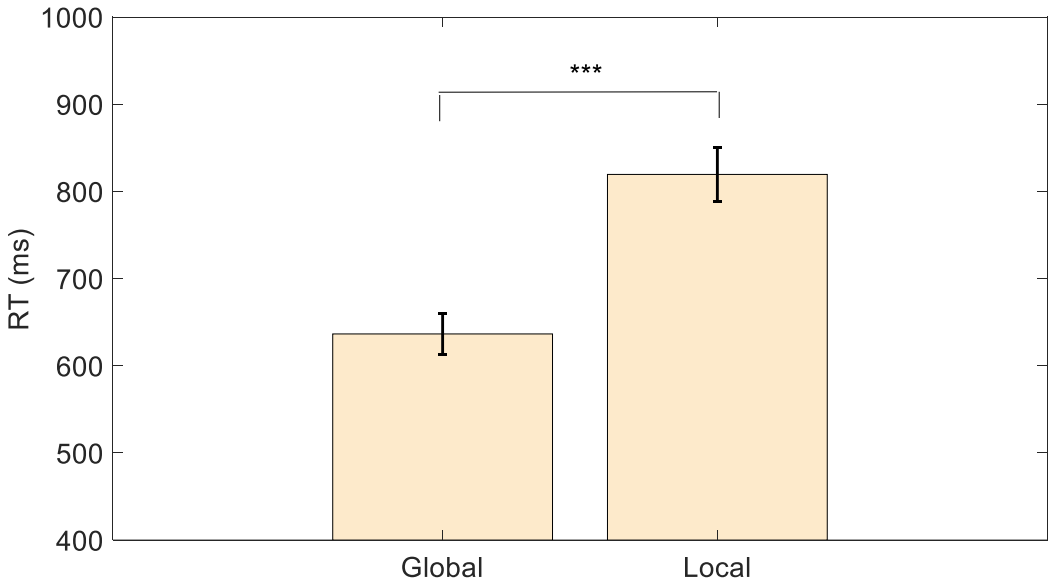
4. General discussion

We found that the global precedence effect was observed in both the Matching judgment (Experiment 1) and Similarity Judgment (Experiment 2) tasks. These results confirm that global precedence effects are present in these different paradigms. Also, it proved that global advantage effects do not need retinal stabilization in task designs.

On the other hand, we introduced a new term "Arbitrary Eccentricity", defined as the eccentricity that an individual unconsciously chooses to perceive the stimuli. We observed a significantly higher average of arbitrary eccentricity in global trials, compared to local trials in both experiments. Previous studies had shown that more eccentricity leads to less resolution and perceptual performance of local details had been decreased in peripheral vision. In this paper, not only this finding is in place, but also, we found that lower 'Arbitrary Eccentricity' is preferred to perceive local features and more distance from fovea is selected unconsciously to save time and energy in global trials. Also, the number of fixations was significantly higher in local trials than in global trials. This finding also confirms the above hypothesis. It seems that in the tasks employing selective attention, that subject knows which level of target should attend to, individuals unconsciously try to use less number of fixations and more eccentricity to explore global information.

Our life strategy for attending is related to how we arbitrary treat to perceive our environment. We automatically prefer to recognize things which are simple and clear to save the energy and the time. So stemming from Pragnanz law in Gestalt, daily moments of life is full of perceiving our perceptual field globally in peripheral vision with less need to eye-movement and only decide to focus foveally when selectively attending to local details seems necessary.

a.



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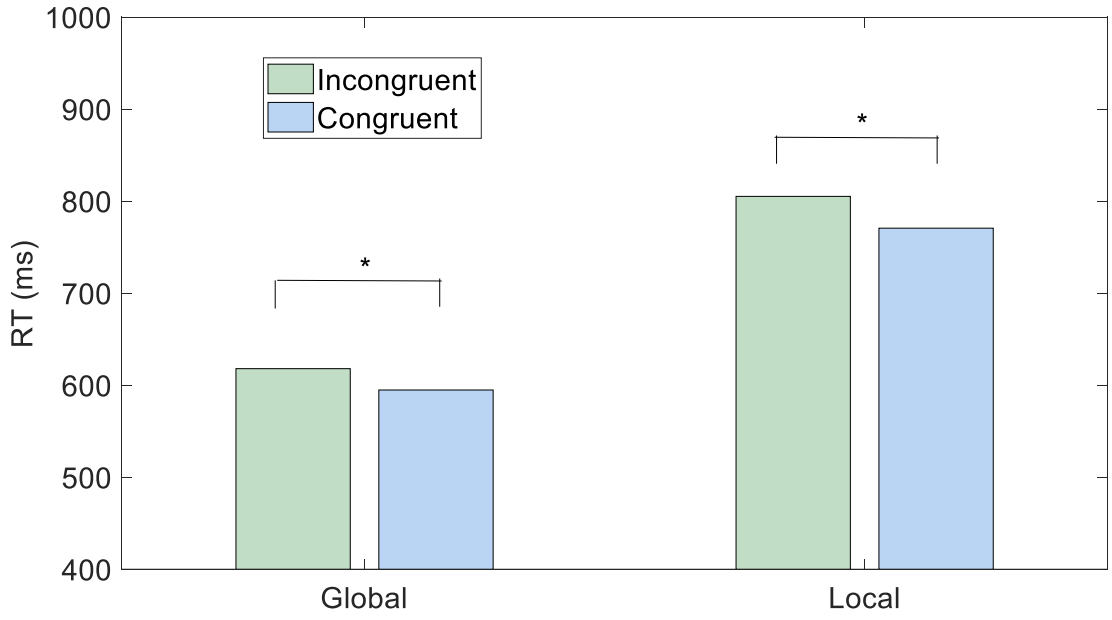
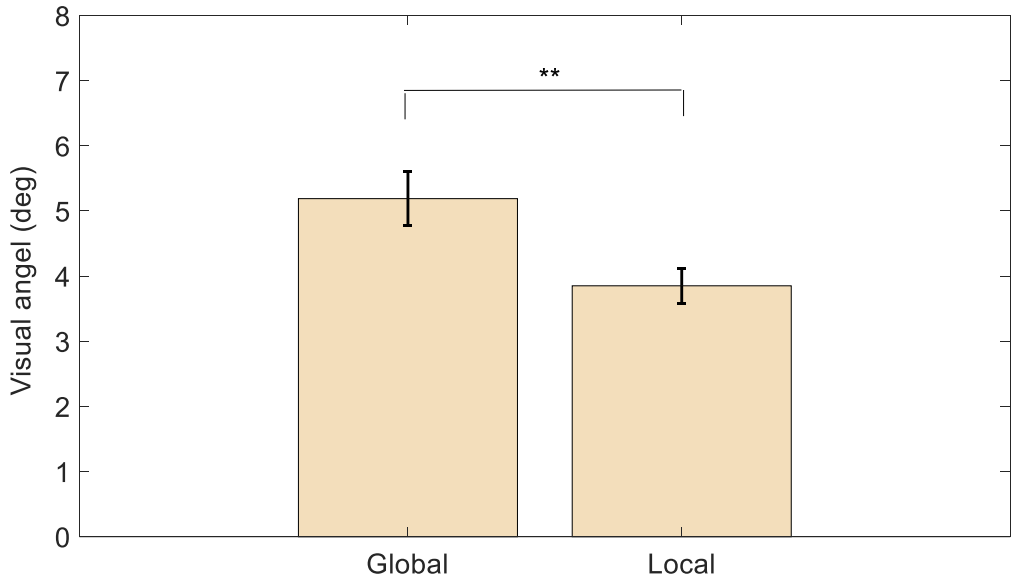


Figure 4. (a) Precedence effect, Average reaction time in global vs local trials in experiment 2. (b) Interference effect, Average reaction time by different congruency.

a.



b.

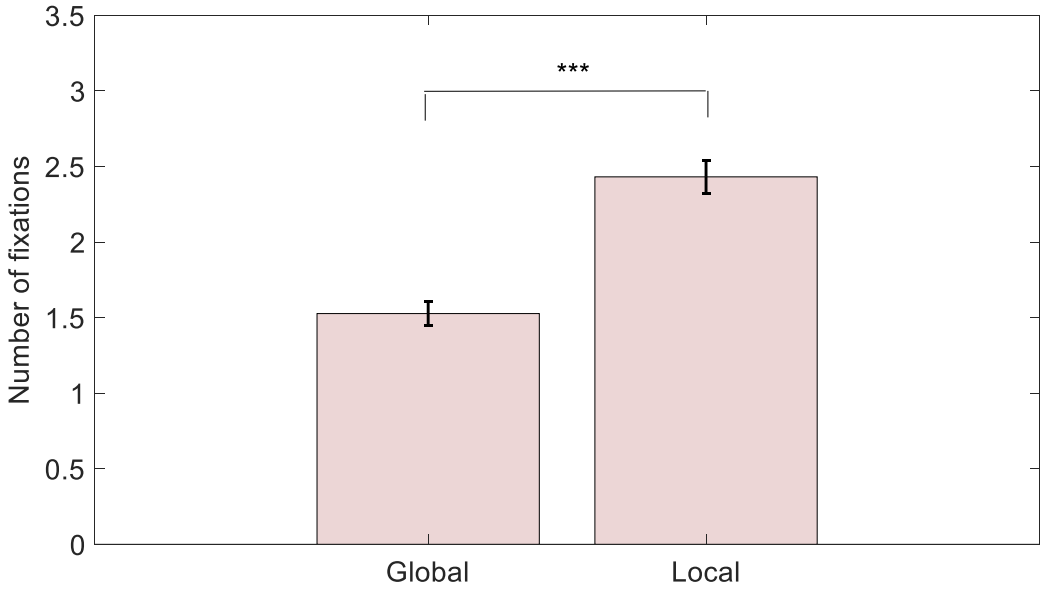


Figure 5. (a) Average arbitrary eccentricity in global vs local trials in experiment 2. (b) Average number of fixations in global vs local trials.

Table 2. Descriptive statistics and paired t-test results for Experiment 2.

		Descriptive Statistics		Paired T-test Statistics		
		M	SD	df	t	P-Value
RT in	global trials	636.46	88.02	13	-10.52	4.93e-08
	local trials	819.45	115.95			
RT in	global congruent trials	594.75	89.02	13	-2.55	0.02
	global incongruent trials	617.94	94.20			
RT in	local congruent trials	870.55	104.41	13	-2.57	0.03
	local incongruent trials	805.11	118.92			
Arbitrary Eccentricity in	global trials	5.18	1.53	13	3.33	0.005
	local trials	3.85	1.00			
Number of Fixations in	global trials	1.52	0.30	13	-8.26	1.57e-06
	local trials	2.43	0.40			

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