Hemispheric Asymmetry in Crowding

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Abstract
This study investigated hemispheric asymmetry in crowding. Four trained observers attempted to identify the tilt of a central Gabor patch among distractors at constant eccentricity and varable spacing. The left visual field-right hemisphere showed more averaging than the right visual field-left hemisphere. This result supports documented global/local asymmetry in processing. The left visual field-right hemisphere also showed a lower threshold for crowding than the right visual field-left hemisphere. Put together, these results partially support a receptive field size mechanism for hemispheric asymmetry. However in order to confirm this interpretation, other measures including modeling should be used in the future.

Hemispheric Asymmetry in Crowding

Hemispheric asymmetry has been empirically described in many domains. In vision, spatial relations judgments and categorical/coordinate judgments show strong converging evidence of hemispheric asymmetry. However, these two observations are only phenomenological descriptions rather than causative evaluations. To this end, this paper attempts to identify an underlying cause for these phenomena through interpretation of a divided visual field crowding study.

Local vs. global decisions show a hemispheric asymmetry in processing. This type of paradigm involves identifying parts of something (local) vs. the whole (global). The classic example involves looking at a forest scene. The local elements of the individual trees compose the global forest scene. The left hemisphere has a faster reaction times for identifying the individual local elements, and the right has faster reaction times for identifying the global scene (Sergent, 1982; Kimchi and Merhav, 1992).

The underlying neural mechanism of this behavioral asymmetry is unknown. However, one potential source of behavioral asymmetries is receptive field size asymmetry between hemispheres. Receptive field size is operationally defined as the range of inputs over which a processing element receives input. Larger receptive field sizes imply a physically larger range of inputs, and smaller sizes imply a smaller range of inputs (Figure 1). If only these differ between the hemispheres, the basic processing element can remain the same (a neuron) while development can influence each element's structure to modulate their properties. These differences could result from differences in axonal length (Quartz and Sejnowski, 1997), dendritic branching (Jacobs, Schall, and Scheibel, 1993), cortical column width (Hutsler and Galuske, 2003), or another currently uninvestigated factor. In the above case, larger receptive fields in the right hemisphere (RH) could allow it better access to the global scene information. This paper attempts to test this theory using a crowding paradigm.

Crowding means an impairment in the ability to identify a visual stimulus when in close proximity to another visual stimulus (Parkes, Lund, Angelucci, Solomon, & Morgan, 2001). In a crowding study, the proportion of correct target identifications is plotted as a function of the independent variable. In this case, the independent variable is the spacing between a central target Gabor patch and surrounding distracter patches. This will result in a plot of spacing vs. proportion correct (Figure 2). The plot will be analyzed for slope and threshold level (point for 75% accuracy). Differences in these parameters represent different requirements for crowding. In this study, subjects were asked to identify the orientation of a tilted central Gabor patch surrounded by an array of horizontal patches (Figure 3). Crowding meant a reduced ability to correctly identify the surrounded patch compared to a patch in isolation.

Crowding is a cortical rather than a retinal phenomena (Parkes et al., 2001). It is also different than ordinary masking (Pelli, Palomares, & Majaj, 2004). Specifically, the visual signal from each element is combined or averaged rather than lost (Parkes, 2001). Its hypothetical mechanism is called a feature integrator which primarily decides what information to exclude perceptually (Pelli et al., 2004). If the receptive field size of the feature integrator is larger in the right hemisphere, the right hemisphere should exhibit more averaging and its threshold for crowding should be higher than the left hemisphere.

Method

Participants

Four observers (CH, EM, VC, and MG) participated in this study. Three (CH, EM, and VC) were naïve to the hypothesis of the experiment. MG was the author of this paper. Participants first trained on a fixation trainer as described in *Fixation Training Without an Eye Tracker* (Leung et al., 2009). Participants could not proceed with the experimental protocol until they were capable of fixating for approximately 30 seconds at a time and could distinguish fixation from non-fixation.

Materials

All stimuli were presented on a 2 GHz Intel MacBook Core II Duo using PsychToolBox Version 3.0.8 in Matlab for Students Version 7.4.0 (R2007a). The screen was an LCD monitor with viewable screen size of 23.8 cm x 18 cm at 1024 x 768 pixels. Subjects were seated so that the screen was 57 cm away from fixation with the fixation point at approximately eye level. Distance was maintained using a chinrest mounted to the table.

Stimuli

Individual Gabor patches consisted of sine wave gratings of 33 pixels per period. The spatial frequency of each pixel was .018 as defined by the ratio of .6 to the pixels per period. Each grid was 200 pixels wide with 1.5 periods covered by one standard deviation of the radius of the Gaussian mask. This amounted to sine wave gratings of approximately 10 cycle/degree (Figure 3).

Each individual patch stayed at a constant size of .63 degrees of visual angle across all trials. These patches were arranged into a radial target array. The array consisted of a central target Gabor patch tilted 15 degrees upwards or downwards from horizontal surrounded circularly by 9 horizontal Gabor patches (Figure 3).

Array spacing was defined as the straight line distance from the center of the target patch to the center of one of the horizontal distracter patches. Array spacing ranged from 0 to .76 degrees of visual angle with gradations of approximately .07 degrees of visual angle (Figure 4).[1]

Procedure

Participants were tested in blocks of 150 trials for a minimum of 750 trials (Figure 5). Blocks were excluded from analysis if they were excessively inaccurate (< 40% accuracy). Each trial started with 1.5 seconds of fixation on a 4 pixel by 4 pixel fixation square. Then, the experimental array flashed 8.9 deg of visual angle to the left or right of fixation for 100 ms. Subjects responded by pressing the “h” key for a downward target tilt and “b” for an upward target tilt. Visual field of presentation (left or right), direction of tilt (up or down), and array spacing was randomly selected for each trial. Across all trials, the eccentricity to the center of the target patch stayed constant at 8.9 degrees of visual angle.

Results

There were two important findings for this experiment. First, LVF-RH is consistently more accurate than the RVF-LH in all subjects (Figure 6). This is visible as the LVF-RH psychometric slope curve being above the RVF-LH. Psychometric slopes were generated by plotting spacing vs. proportion correct using MatLab’s curve fit tool for the equation $f(x) = 1/(1+\exp(-1*(x-a)/b))$. Individual participant data are in Table 1.

[1] There was a mistake in coding which resulted in spacing differences of .07 deg of visual angle between most spacings and .05 deg of visual angle between two spacings.

Second, LVF-RH has a lower threshold of borderline significance for crowding than RVF-LH, as determined by a repeated measures t-test performed on the extracted threshold points from the generated psychometric slope functions, $t(3) = -2.776$, $p = .069$. Individual participant psychometric slope equations are in Table 2.

Discussion

The first result of this experiment is unsurprising. The right hemisphere is consistently more accurate than the left. Because crowding represents averaging of visual information, this shows that at each spacing more averaging is occurring in the right hemisphere. This results in a higher proportion correct for each spacing. This result coincides with existing local/global asymmetry and the receptive field size asymmetry hypothesis.

The second result of this experiment is surprising in light of the receptive field asymmetry hypothesis. With larger receptive fields in the right hemisphere, it is expected to show a higher threshold for crowding. However, my results show a lower threshold for crowding in the right hemisphere. The most plausible, empirically supported reason is the nature of the feature integrator and the crowding paradigm itself.

In addition to local/global judgments, categorical/coordinate judgments show hemispheric asymmetry in processing (Kosslyn, 1987). The judgment of a particular stimulus as in one category compared to another is called a categorical judgment. Categorical judgments would include describing one stimuli as to the left/right or above/below another stimuli. Judgment of the metric distance between the stimuli is called a coordinate judgment. The left hemisphere shows faster reaction times to categorical judgments, while the right has faster reaction times to coordinate judgments (Kosslyn, 1987).

Differences in receptive field size could account for the categorical/coordinate asymmetry as well (Kosslyn and Jacobs, 1994). With a small, fixed range of input in the left hemisphere, a single processing element could quickly identify a stimulus as present or absent in a region (Figure 7). This type of processing explains the left hemisphere advantage for categorical judgments. However, a coordinate judgment requires more precise location information and subsequent comparison between processing elements. With larger receptive fields in the right hemisphere, there is more overlap between individual processing elements. Comparing a fixed amount of processing elements shows that the larger overlapping receptive fields in the right hemisphere could more precisely define the region in space of a particular element (Figure 7).

The same logic can be applied to the lower threshold for crowding in the right hemisphere. The feature integrator is primarily exclusive in nature. It decides primarily what information to exclude to the point that its receptive field has been described as an "isolation field" (Pelli et al., 2004). The right hemisphere could be more precisely identifying what information to average and what to exclude.

This experiment at the very least seems to successfully show that the right and left hemispheres have different requirements for crowding. While the receptive field size explanation is interesting and compelling, it is not complete. Further analysis is required in order to adequately explain this phenomena. Specifically, some sort of modeling should test the categorical/coordinate explanation of the lower crowding threshold in the right hemisphere. Also, another experiment should show that increased right hemisphere averaging hurts performance with distractors whose orientation vastly differs from the target.

References

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Acknowledegments

I would like to thank Dr. Michael Morgan of The City University in London for the code this experiment was based on. I would like to thank Heeyoung-Choo, PhD candidate at Northwestern University for her help interpreting that code and designing my own. I would like to thank Dr. Steve Franconeri for his help interpreting the results. Lastly, I would like to thank Dr. Mark Jung-Beeman for his inspiration in coming up with the theory behind this experiment.

Table 1

Participant CH

Spacing	0	0.08	0.15	0.22	0.37	0.34	0.41	0.48	0.55	0.62	0.69	0.76
LVF – RH	*46%*	*58%*	*80%*	*79%*	*91%*	*93%*	*96%*	*97%*	*100%*	*100%*	*100%*	*100%*
RVF – LH	*50%*	*68%*	*73%*	*58%*	*63%*	*100%*	*92%*	*94%*	*97%*	*98%*	*94%*	*90%*

Participant EM

Spacing	0	0.08	0.15	0.22	0.37	0.34	0.41	0.48	0.55	0.62	0.69	0.76
LVF – RH	*60%*	*68%*	*77%*	*76%*	*68%*	*90%*	*84%*	*87%*	*100%*	*97%*	*90%*	*96%*
RVF – LH	*46%*	*71%*	*50%*	*59%*	*62%*	*57%*	*66%*	*81%*	*82%*	*72%*	*75%*	*79%*

Participant VC

Spacing	0	0.08	0.15	0.22	0.37	0.34	0.41	0.48	0.55	0.62	0.69	0.76
LVF – RH	56%	68%	68%	55%	58%	68%	71%	85%	84%	87%	92%	90%
RVF – LH	46%	44%	52%	40%	58%	61%	63%	79%	82%	76%	68%	87%

Participant MG

Spacing	0	0.08	0.15	0.22	0.37	0.34	0.41	0.48	0.55	0.62	0.69	0.76
LVF – RH	45%	55%	69%	77%	79%	70%	56%	73%	78%	84%	75%	93%
RVF – LH	46%	54%	49%	70%	56%	63%	67%	70%	72%	73%	78%	87%

Table 2

Subject CH

	Left VF-RH	Right VF-LH
R-Squared	0.978	.718
Slope	.119	.213
Threshold	.154	.225

Subject EM

	Left VF-RH	Right VF-LH
R-Squared	.821	.601
Slope	.279	.570
Threshold	.190	.596

Subject VC

	Left VF-RH	Right VF-LH
R-Squared	.745	.790
Slope	.407	.387
Threshold	.389	.582

Subject MG

	Left VF-RH	Right VF-LH
R-Squared	.560	.846
Slope	.487	.482
Threshold	.451	.587

Figure Captions

Figure 1 – Illustrated left vs. right hemisphere receptive field size

Figure 2 – Example of a psychometric slope

Figure 3 – Gabor array stimuli

Figure 4 – Target-distractor spacings

Figure 5 – Diagram of experimental procedure

Figure 6 – Individual observer psychometric slopes

Figure 7 – Receptive field size mediation of categorical/coordinate advantage.

Figure 1

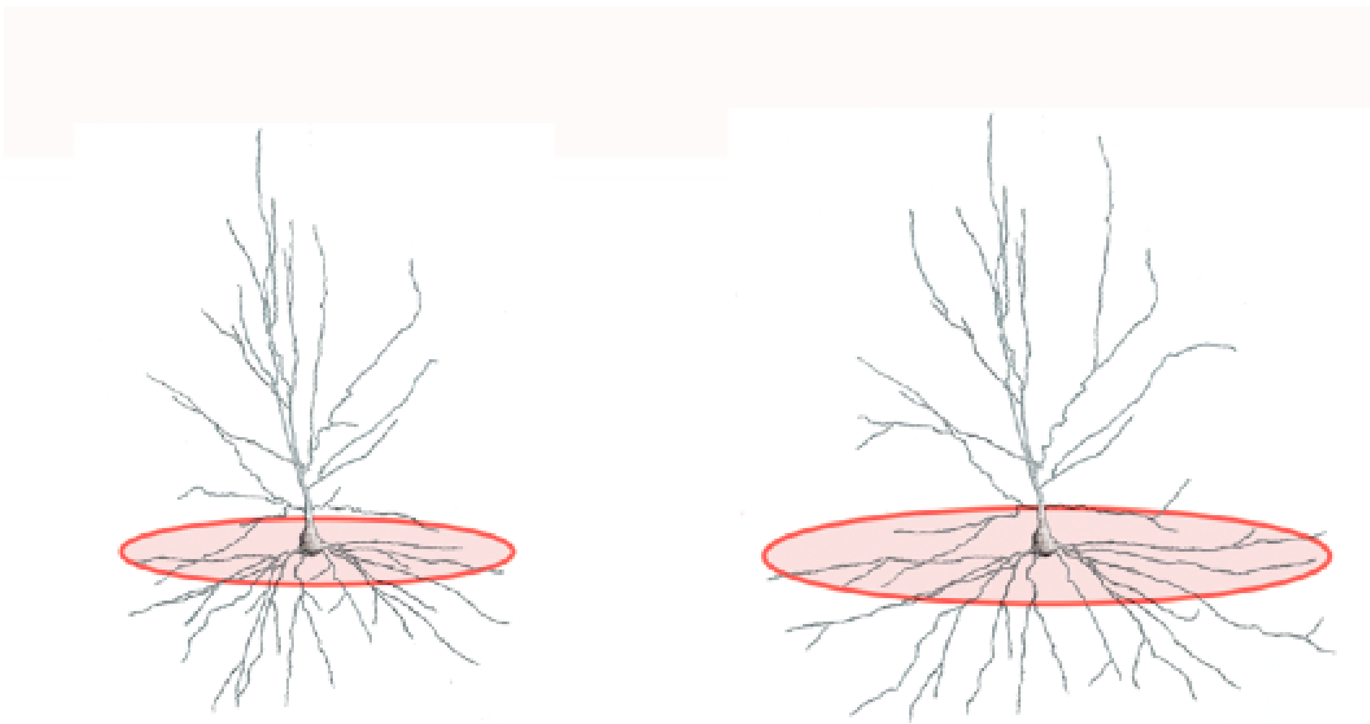

Figure 2

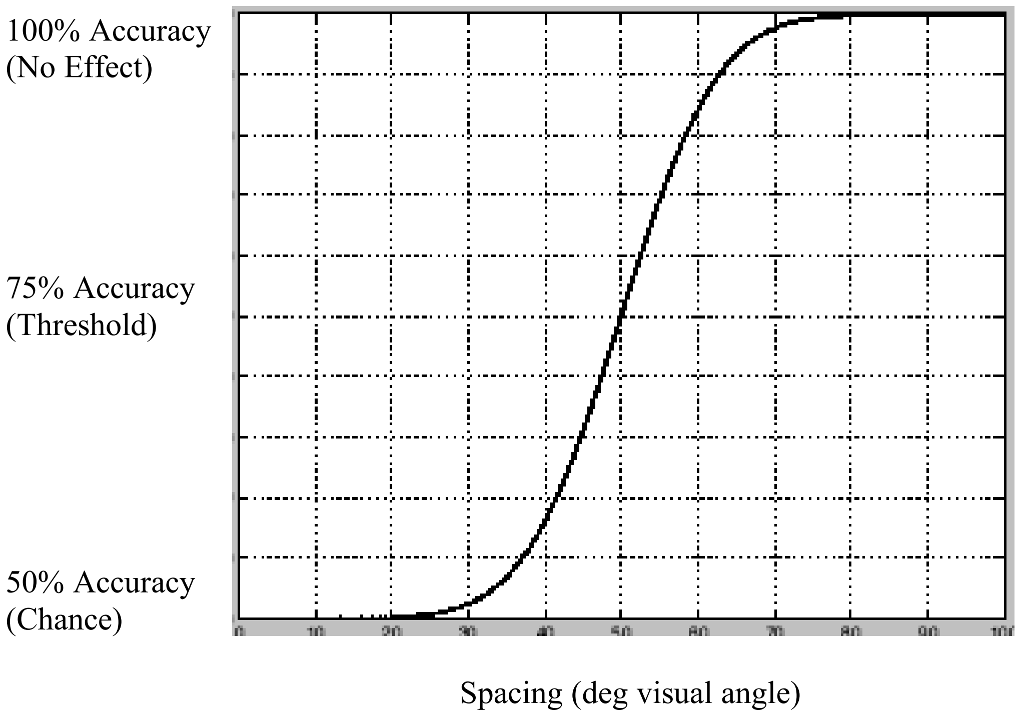
100% Accuracy
(No Effect)
75% Accuracy
(Threshold)
50% Accuracy
(Chance)
0
10
20
30
40
50
60
70
80
90
Spacing (deg visual angle)

Figure 3

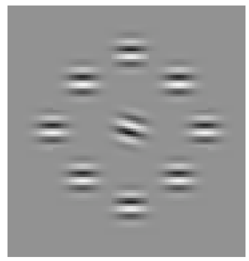

Figure 4

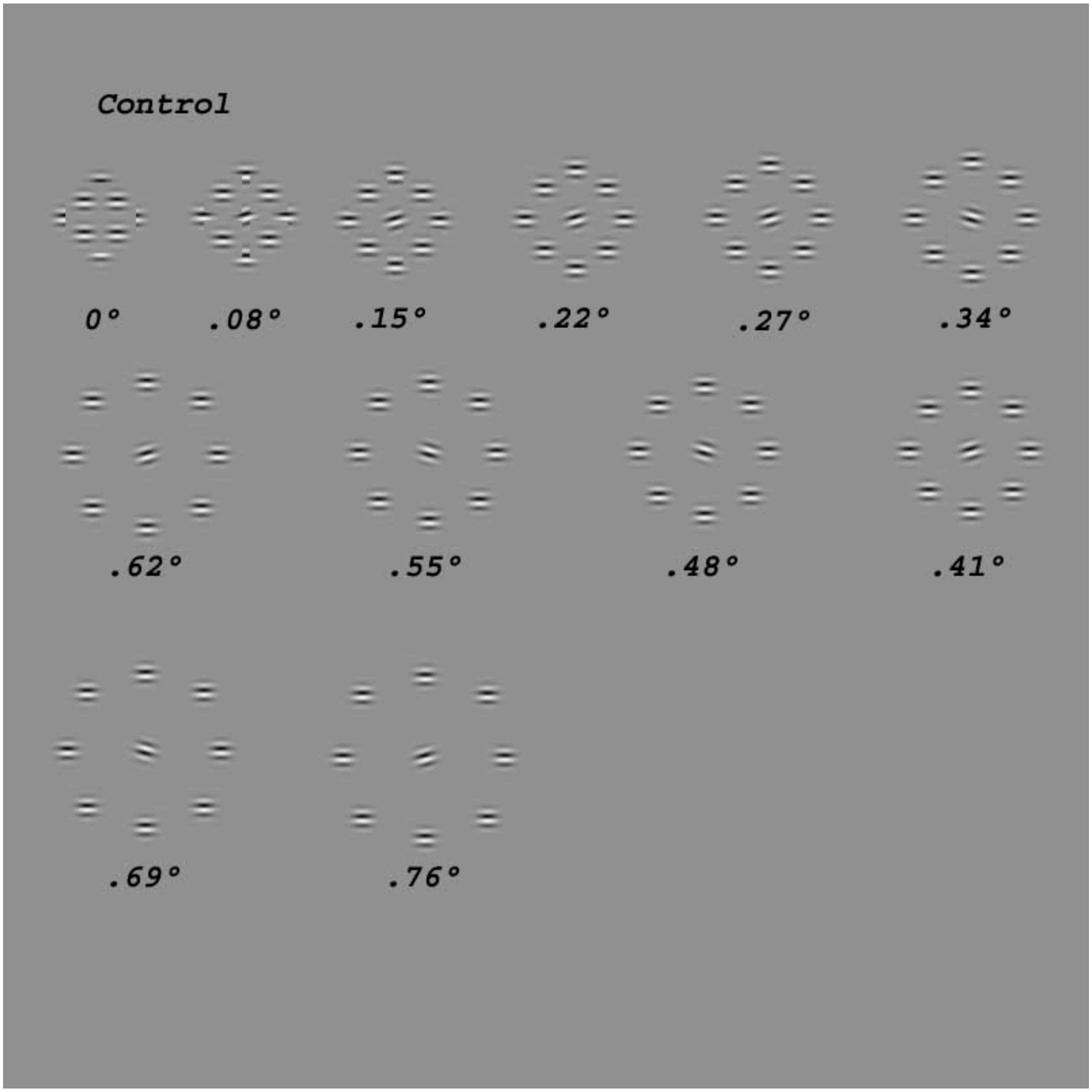

Figure 5

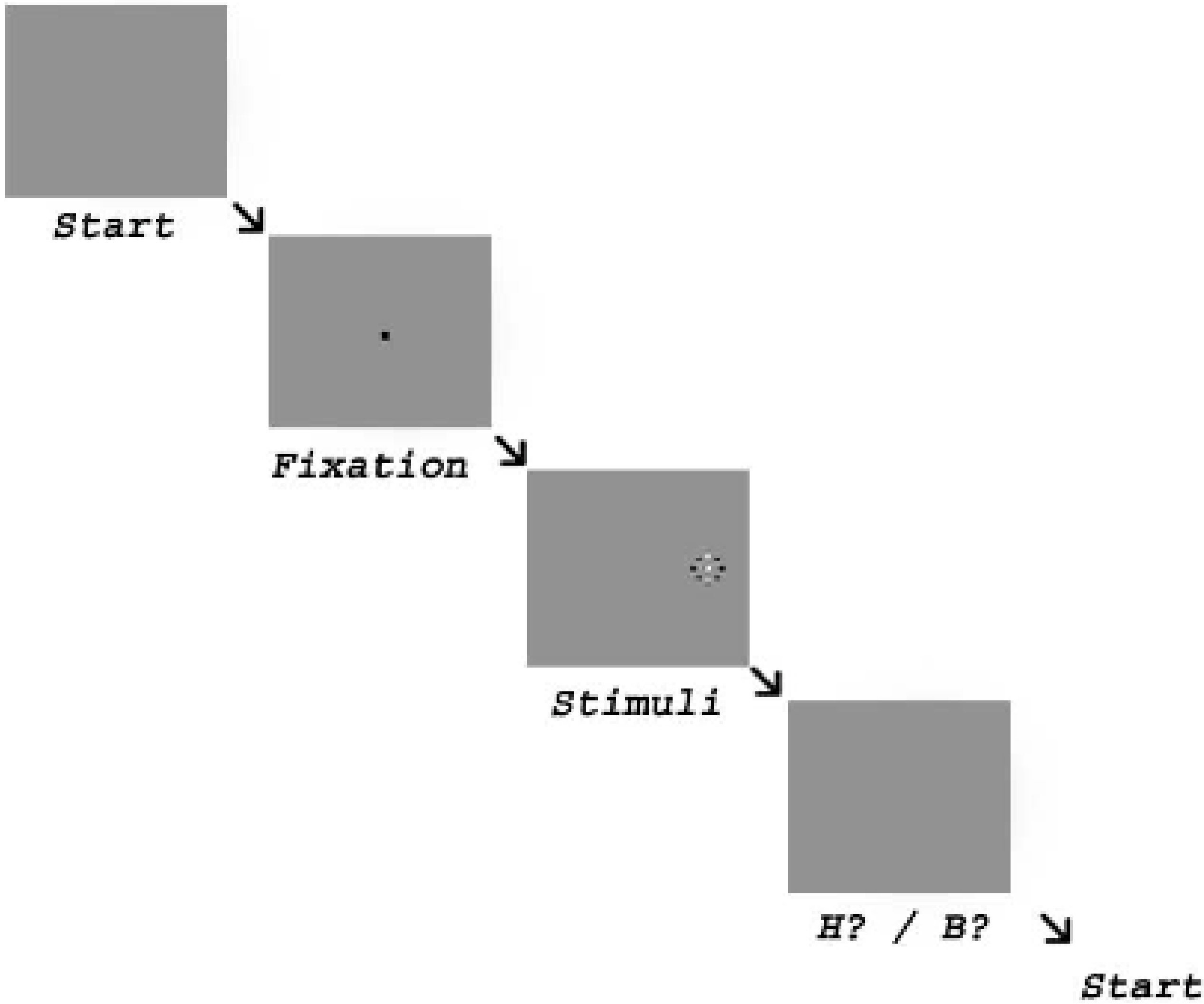

Figure 6

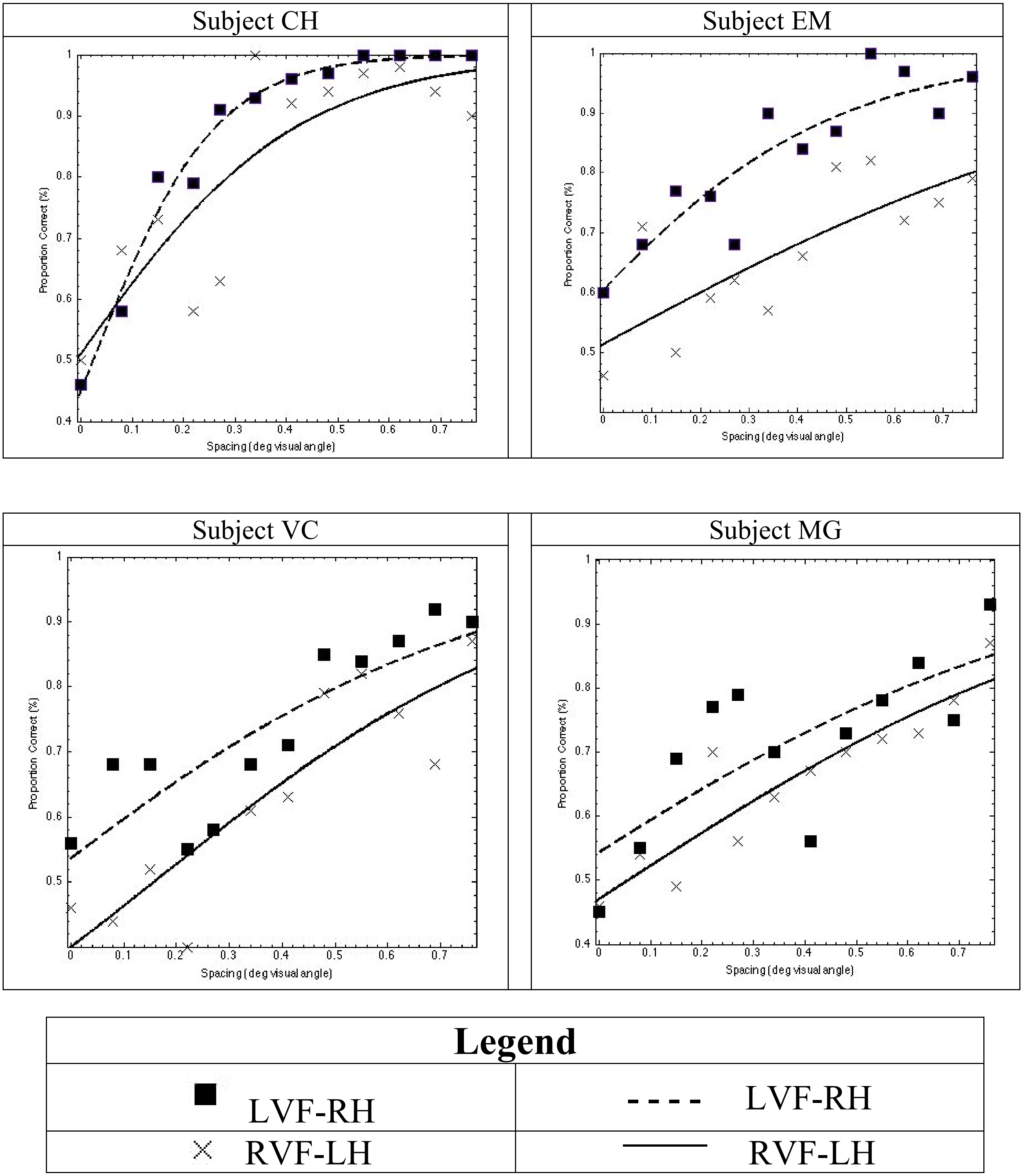
Subject CH
Subject EM
Subject VC
Subject MG
Proportion Correct (%)
Spacing (deg visual angle)
Legend
LVF-RH
RVF-LH
LVF-RH
RVF-LH

Figure 7