TEMPORAL ASYNCHRONY IN CONTOUR INTEGRATION

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PURPOSE

Evidence that visual grouping is facilitated when elements comprising a foreground figure are presented simultaneously, and are temporally separated from elements comprising the background, has suggested cortical synchronous oscillations as a possible neural substrate. Supporting this theory, Usher & Donnelly [1] showed that contour integration is indeed facilitated when path and background elements alternate with an asynchrony below the integration time of the visual system, suggesting that these flickering stimuli interact with this hypothetical binding mechanism. I investigated this puzzling result using a standard contour integration paradigm [2-4].

METHODS

The task requires the linking of orientation across space to detect a ‘path’ [2]: stimuli were arrays of oriented band-pass elements (Gabor patches of 1.5 cpd, $\sigma = 0.17$ deg) randomly positioned within a 14 x 14 degree square grid, in which 10 adjacent elements were aligned along a path. Paths of fixed curvature (20 deg) and fixed contrast (50%) were used. Stimuli were generated in real-time on a Cambridge Research Systems VSG 2/4. Path detection was measured using a temporal 2AFC method of constant stimuli with path and no-path intervals, and with a 500 ms inter-stimulus interval. Feedback was given after each trial, and a black fixation mark appeared in the centre of the stimuli. Subjects were 1 experienced and 2 naive observers with normal, or refracted to normal vision. All experiments were done under binocular conditions.

EXPERIMENTS

In experiment 1, I explored the effect of various onset asynchronies (13 and 26 ms) between path and background elements as a function of the stimulus duration (13-250ms) in a steady rather than flickering presentation. One should expect that contour detection would be improved if the segmentation between path or background elements is already established when the full stimulus (path and background elements together) is switched on [5]. Three conditions were considered: 1) a synchronous condition, 2) a path-first asynchronous condition, 3) a background-first asynchronous condition. In both asynchronous conditions, the full stimulus was followed by a 500ms orientation-masking stimulus [3], while a "sandwich-masking" paradigm was used in the synchronous condition.

In experiment 2, I replicated Usher & Donnelly's experiment and controlled for stimuli order. Path and background elements were flickered in counter-phase at 38Hz (13 ms asynchrony) and for various duration (26-210 ms). Three conditions were considered: 1) synchronous, 2) asynchronous with a 13 ms advance for the path elements (path-first), 3) asynchronous with a 13 ms advance for the background elements (background-first).

RESULTS

1) Contour integration is strongly primed by path elements: i) path-first performance is already optimal for the shortest duration (13ms), while background-first and synchronous performances rise smoothly with stimulus duration; ii) the shortest delay (13 ms) is as effective as the longest for path-first, while longer delays boost the performance for background-first; iii) synchronous performances are generally lower than background-first performances, rise even more slowly, and cannot compensate, at the same total duration, for the gain in path-first performance.

2) Facilitation depends on the asynchrony order in the first cycle: i) performance rises smoothly with stimulus duration until reaching an asymptotic level; ii) both asynchronous conditions show a slight advantage below 100 ms, while path-first performance is significantly higher (by about 10%) only above 100 ms; iii) background-first and synchronous performances saturate at the same level.

CONCLUSIONS

1) The visual system is highly sensitive to short onset asynchronies between path and background elements, and the underlying transient mechanism retains the orientation of stimulus elements to prime contour integration in the subsequent test stimulus.

2) Contour integration is facilitated only when path elements are presented before background elements in the first cycle of the stimuli sequence, and not at all when background elements precede path elements. This suggests that Usher & Donnelly's effect may depend primarily on the order of stimuli sequence rather than on temporal asynchrony per se.

We conclude that Usher & Donnelly's result is likely due to the high sensitivity of the visual system to stimulus onset, and that simple flickering stimuli are inadequate for revealing the neural code for binding in figure-ground segregation without appropriate control experiments.

References

1. Usher M, Donnelly N (1998) *Visual asynchrony affects binding and segmentation in perception.* Nature 394, 179-182.
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3. Hess RF, Beaudot WHA, Mullen KT (2001) *Dynamics of contour integration.* Vis. Res. 41(8):1023-1037.
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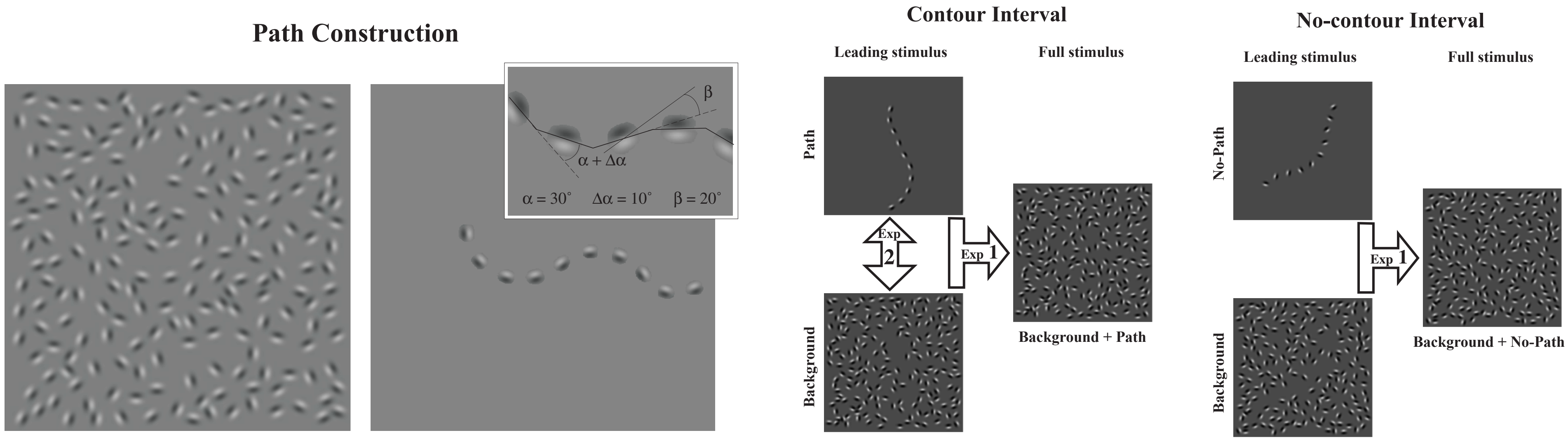
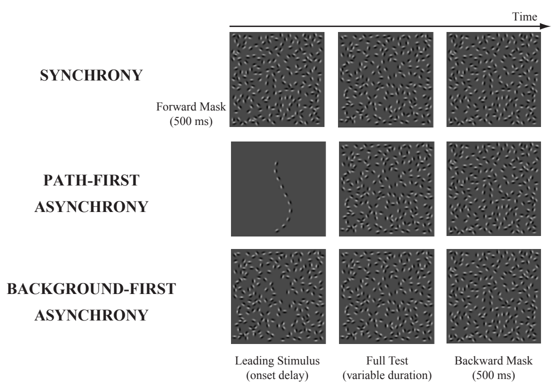
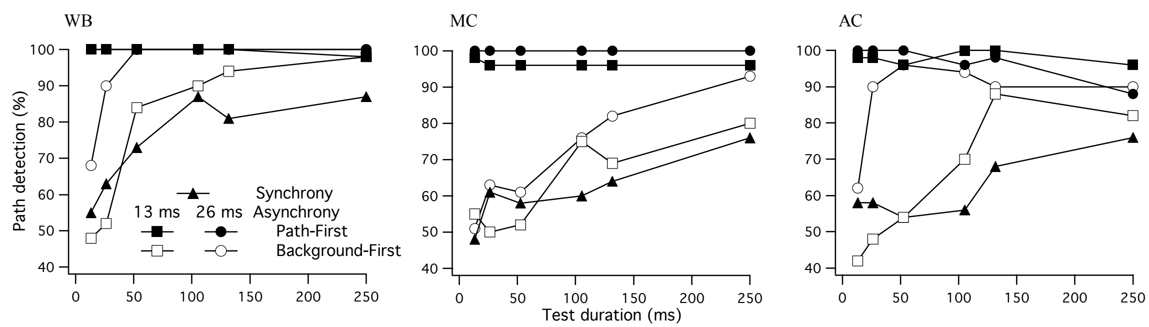
5. Ziebel O, Nothdurft HC (1999) *Cueing and pop-out.* Vis. Res. 39(12):2113-2125.

STIMULI



EXPERIMENT 1: Effect of Onset Asynchrony





EXPERIMENT 2: Replication of Usher & Donnelly's Experiment