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1 Experiment 2

In section ??we saw that the perceived direction of motion is more sensitive to the carrier motion when spacing is small but more sensitive to envelope motion when spacing is large. . However, because the stimulus consists of a varying number of elements spaced evenly around a circle, the count of elements in the stimulus is confounded with the spacing, between elements, one being inversely related to the other. Therefore in order to confirm that the sensitivity to displacement is a function of element spacing rather than number, we should attempt to distinguish the two factors.

Similarly, our proposed mechanism of obligatory summation is characterized as a function of the product of the carrier direction content with the element density (i.e. the inverse of the spacing); in ?? this factor has been confounded with the total motion energy in the scene (i.e. direction content multiplied by number of elements.) To verify that the degree of bias depends on spacing rather than total motion energy, we should try to distinguish spacing from element number.

Another goal was to determine whether there were differences in performance dependent on the location of the elements in the visual field. This may give additional clues to the the nature of mechanisms underlying the perception of motion direction. Depending on which cortical areas are involved in generating a perception of motion, we may see more or less interference between moving objects For example, the numeric limit on object tracking appears to be independent between left and right hemifields [1]. In contrast, if the reversal shares mechanisms with crowding effects, then we might expect a lessened crowding effect for stimuli that span the horizontal meridian (, but see...) There are a few overlapping reasons why we would wish to experimentally distinguish element spacing from element number.

1. Studies of the "multiple object tracking" task [3] have shown that when observers attentively track a subset of objects moving among distractors, there appears to be a limit to the number of objects whose changes in position can be tracked for later identification. Adding more elements to our display might then interfere with the ability to individuate and track each element, leading to the inability to correctly discern their change in position over time. Although the number of elements whose global motion can be correctly discerned in our display is substantially larger than the limits usually found in MOT studies, the elements also move coherently, consistent with a structural rotation of the stimulus, which may increase the capacity for tracking [5].

2. For similar reasons, element spacing in section **??** is also confounded with the aggregate amount of motion energy; reducing spacing requires adding more elements, which contributes more motion energy. Some motion mechanisms may sum up short-range motion information over large regions of the visual field; for example, global optic flow patterns such as rotations produce aftereffects in quadrants of the visual field that did not contain the adapting stimulus[4], suggesting a mechanism tuned to optic flow that integrates large areas of the visual field. Since the patterns of carrier and envelope motion in our stimulus are (considered separately) consistent with a global rotation, channels sensitive to global rotations are likely to contribute to the appearance of our stimuli. If these detectors are more sensitive to first-order than than higher order motion, motion[2], merely adding more elements my tip the balance toward the short-range component of the stimulus.

3. A third reason concerns the induced motion effect we observed at larger element spacings. Do these effects depend on element number???

Therefore we wished to know whether the apparent reversal of the stimulus as a function of element spacing could be explained as an effect of the number of elements instead. Our approach was to show elements covering only a portion of the annulus, so that fewer elements were displayed at the same density.

1.1 Methods

- Show stimulus design; covarying element number and density
- Mention flankers, which are not counted as moving elements
- Show demo movie, numbers linked to stimulus space
- Mention how displacement and direction content is chosen, based on data from Experiment 1, in an ad-hoc manner. Illustrate with comparisons of Exp 1 and Exp 2 data from illustrative subjects (NJ, PBM)
- We also test in alternate hemifields blockwise (but this is less important.)
- SUBTLE BUT IMPORTANT POINT: It's the slope of the lines that matters most, not their height or the change in height with element number (which is explained away as full-field sum of motion-energy). Whether the lines collapse together plotted against spacing, as PBM, or collapse plotted versus number, as NJ, doesn't actually matter. What matters is that In particular, it's that the slope does not change with element number, that distinguishes this model from e.g. one in which element number causes collapse due to failure of attentive tracking or whatever. Work through why the model predicts this.

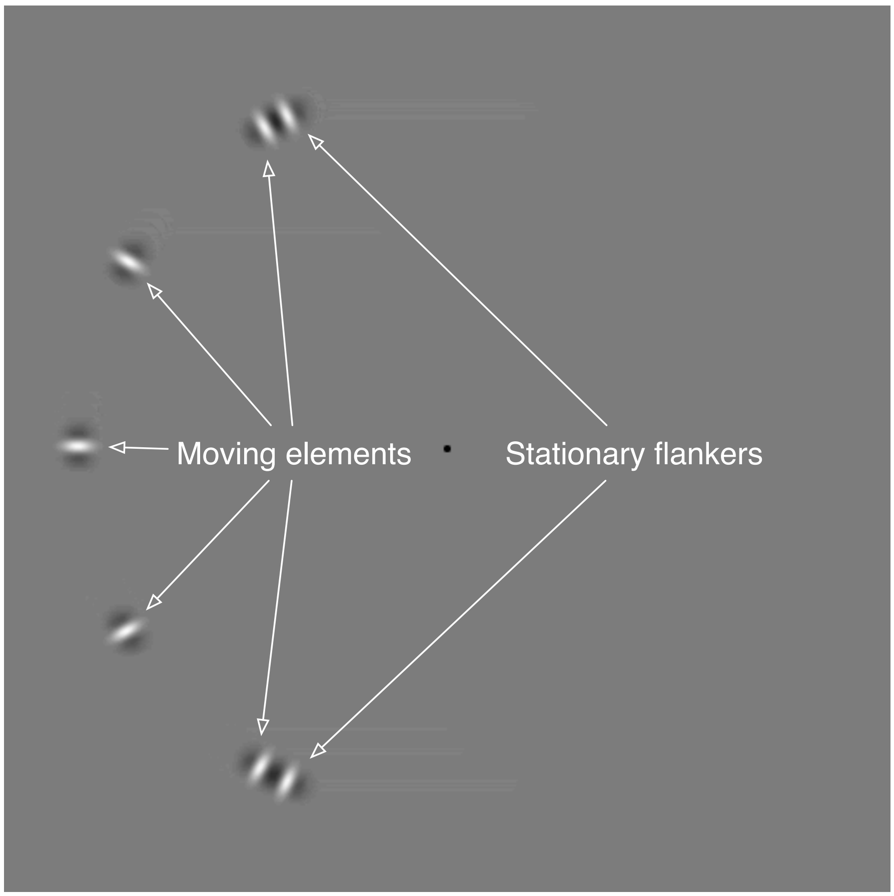

Figure 1: Example frame from a partial-circle stimulus. A number of moving elements are present on one side of the display. Two additional flanking elements are added, which always have carrier motion of 0. The flanking elements are positioned $0.5, 1^\circ$ away from the nearest moving elements at their closest approach.

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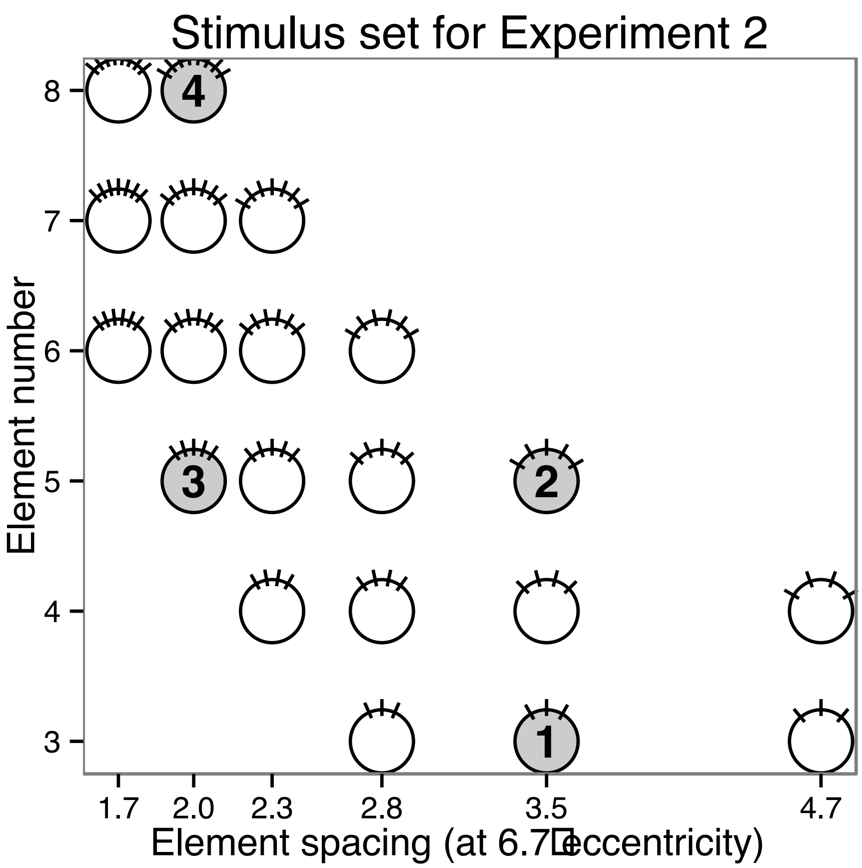


Figure 2: The combinations of element spacing and element number used in this experiment. Tick marks on symbols depict variations in spacing and number (which are also shown on the X axis.) Numbers reference stimuli demonstrated in Figure 3

Figure 3: Example stimuli for Experiment 2. In this movie, the elements are shown in the left hemifield; in the experiment, elements were shown in the right hemifield. Two stationary flankers with null carrier motion are present in all stimuli. Stimuli numbered 1 and 2 have identical numbers of targets, with large, then small spacing. Stimuli 3 and 4 show targets with identical spacing, with fewer and then more targets. The numbers correspond to stimuli marked with a number in The combinations of element spacing and element number used in this experiment. Tick marks on symbols depict variations in spacing and number (which are also shown on the X axis.) Numbers reference stimuli demonstrated in Figure 3

Figure 4: Alternative predictions for Experiment 2. We show a collection of psychometric functions, stratified by spacing, that we collected in **??**. The vertical line indicates a value of spacing that was selected for this subject to use in Experiment 2. In the left column we show a prediction for how the proportion of responses answering "clockwise" for these stimuli should vary with the element spacing in Experiment 3, all other parameters being equal. This corresponds to the intercepts of each point in the upper graph through the graph. This prediction is based on the model fit to Experiment 1, presuming that the decline in sensitivity seen by the is a function of element spacing. In the right column, we show a prediction made similarly but presuming that the decline in β_{Δ_x} observed in **??** depends on element number. The fit is clearly better for the model in which β_{Δ_x} is a function of spacing rather than number.

The task was identical to that in **??**; The stimulus was fixed at degrees eccentricity. The stimulus consisted of a number of moving elements, identically specified to those in **??** but instead of being evenly distributed around a circle, the elements were distributed in a limited area on either the left or right wide of the display. We varied both the spacing and the number of elements used; accordingly, the total spatial extent of the stimulus varied from trial to trial. The values of spacing and element count we used are shown in The combinations of element spacing and element number used in this experiment. Tick marks on symbols depict variations in spacing and number (which are also shown on the X axis.) Numbers reference stimuli demonstrated in Figure 3. This stimulus set was constructed so that each value of element spacing was tested using more than one value for the element count, and vice versa. We chose a set of stimuli that were symmetrically arranged in number and density, spanning a similar range for both variables (covering a factor of NaN in element number and a factor of 2.78 in element spacing.)

We found it necessary to include two stationary flanking elements, indicated in Example frame from a partial-circle stimulus. A number of moving elements are present on one side of the display. Two additional flanking elements are added, which always have carrier motion of 0. The flanking elements are positioned $0.5, 1^{\circ}$ away from the nearest moving elements at their closest approach.. These served to hide the displacement of the moving elements at either end of the display, which would otherwise be easier to discern lacking a crowding flanker on one side. The flanking elements had zero envelope movement and null carrier direction (i.e. their carriers flickered in counterphase.) The flanking elements were positioned so that they were $0.5, 1^{\circ}$ away from the adjacent moving element at its closest approach; this allowed that there was not a conspicuous gap opening or closing between the flanker and moving elements as the moving elements underwent envelope displacement. The flankers spanned an angle that was at least 56° and no more than 165° (in terms of the angle formed by two segments each connecting one of the outermost moving elements to the fixation point. The movie shown in Figure 3demonstrates the stimuli with flanking elements, for the four configurations indicated with numbers in The combinations of element spacing and element number used in this experiment. Tick marks on symbols depict variations in spacing and number (which are also shown on the X axis.) Numbers reference stimuli demonstrated in Figure 3.

The particular values of direction content and envelope motion were chosen for each subject based on preliminary findings of Experiment 1. This choice was made by the experimenter with the goal to select values that would elicit a useful effect of element spacing (see Figure 4)

Since the strength of crowding is typically not uniform and varies between hemifields, we tested stimuli positioned in the left and right visual fields. Each session used an equal number of stimuli left wand right, which alternated in blocks of 100 to 200 trials.alternating in blocks of .

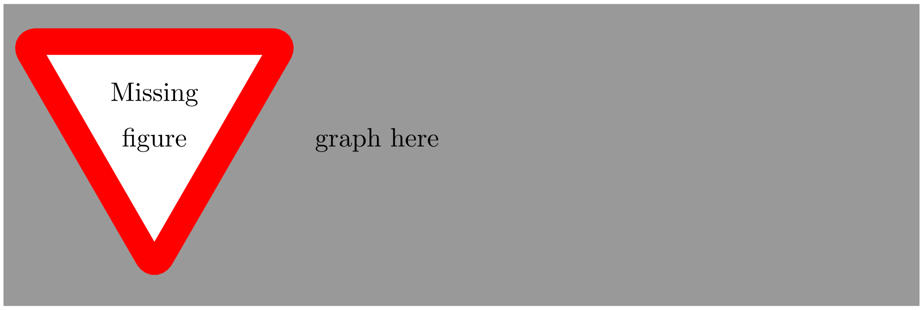


Figure 5: Example data from Experiment 2, below, compared to data from **??**. The vertical line shows the value of displacement chosen by the experimenter for use in Experiment 2; this stimulus configuration was anticipated to show an effect. Below, the data that was collected at this stimulus configuration.

1.2 Results

Of the subjects who had previously participated in **??**, 8 participated in section 1. Basic results are shown in Figure 6. Each plot shows the rate at which subjects responded "clockwise" to a stimulus. Some subjects were tested using more than one value of envelope displacement and/or carrier direction content as in Figure 1, but results were qualitatively similar between sessions so these are shown averaged. Although there appear to be qualitative differences, there are also substantial similarities. For example, the responses of observer NJ appears to be determined "by number," where the lines of constant spacing are relatively flat, but there is a large effect of changing the element number. By contrast, observer PBM appears to respond "by spacing", in that the lines traced by varying spacing while holding element number constant appear to collapse onto each other. Other subjects appear to have intermediate behaviors. At first glance it would appear that these subjects are using different rules to perform the task. However, interpreting these patterns of behavior in detail requires correlating them with the measurements from **??**; since the earlier experiment suggested more than one mechanism that could contribute to an observer's perceived direction of motion, what appear to be different patterns of response may be a result of differing strengths of contribution of each respective mechanism.

Despite apparent differences, the behavior of all subjects exhibits commonalities. Each subject's rate of response changes progressively with different values of spacing; changing element spacing while holding element number constant has a similar magnitude of effect regardless what the number of elements is. The converse is also true; changing the number of elements while holding spacing constant has consistent effects within each subject's data.

Figure 6: Subjects' responses to stimuli that covary in terms of number and in density. In each graph, the number of elements clockwise represents the

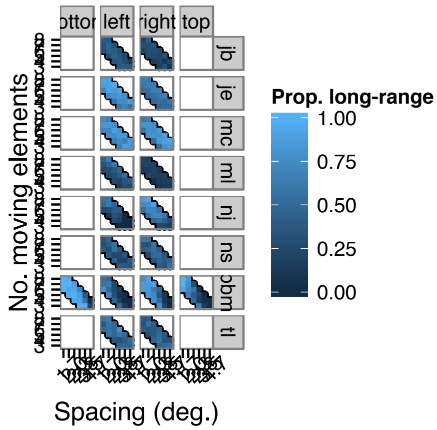


Figure 7: Results from a mixture of element numbers and spacings. Colors indicate proportions of responses in agreement with the long-range motion direction.

1.2.1 Agreement with results of ??

We asked how well the results from section 1 could have been predicted by the model discussed in **??** and fit to data taken from Experiment 1. To do this, we need to disambiguate the meaning of the coefficients β_{Δ_x} and β_S; these were described in **??** as being functions of element spacing, but **??** does not distinguish this possibility from the possibility of being a function of element number. We used the model fit by experiment 1 to form predictions for Experiment 2 as follows; first we

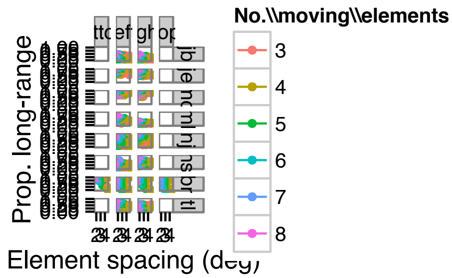
Since **??** does not establish how large the

Effects of stimulus location

* left versus right hemifield has a slight difference. Connect with other literature on crowing.

Effects of eye movements

* there are none...



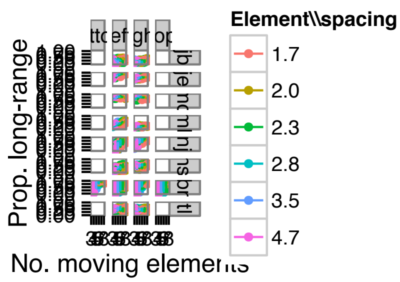
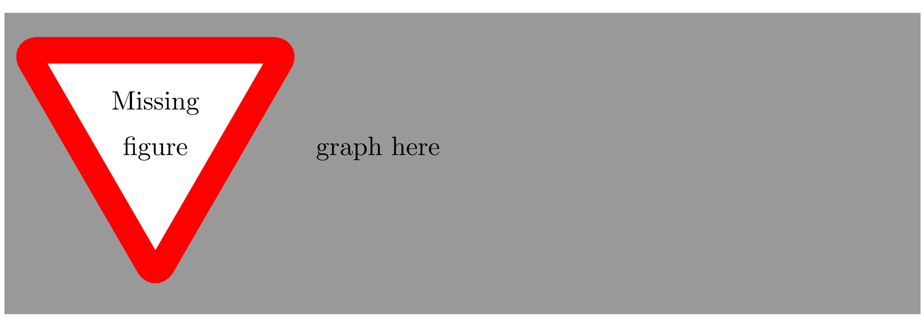


Figure 8: In the upper plots, the proportion of responses agreeing with long range motion is plotted as a function of the number of the element spacing. Data is grouped according to the element spacing and separate lines are drawn for each spacing. In the lower plots, the proportion of responses agreeing with long range motion direction is plotted as a function of the number of moving elements, with data grouped by the spacing used.



(a) The effects of both element number and element spacing are estimated using a logistic regression model. Logistic regression coefficients for each subject. (stacked bar graph) A multiple logistic regression was used to apportion subjects' responses to element count (red bars) or to element spacing. Positive values for the density coefficient indicate that the proportion of responses agreeing with local motion increased when density increased, holding elmeent number constant; vise versa for the count coefficient.

Figure 9: Results of density/number experiment.

References

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