

Reaction time asymmetries between expansion and contraction

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Different asymmetries between expansion and contraction (radial motions) have been reported in the literature. Often these patterns have been regarded as implying different channels for each type of radial direction (outward versus inwards) operating at a higher level of visual motion processing. In two experiments (detection and discrimination tasks) we report reaction time asymmetries between expansion and contraction. Power functions were fitted to the data. While an exponent of 0.5 accounted for the expansion data better, a value of unity yielded the best fit for the contraction data. Instead of interpreting these differences as corresponding to different higher order motion detectors, we regard these findings as reflecting the fact that expansion and contraction tap two distinct psychophysical input channels underlying the processing of fast and slow velocities respectively.

Humans, and animals in general, often have to interact with moving objects. The situation where a target moves along the observer's line of sight is particularly interesting because it usually implies trajectories that the observer either has to avoid or intercept. This type of motion in depth generates radial motion (expansion or contraction) in the retinal image. How radial motion is processed by the visual system is still under debate. The most likely possibility is that higher order motion detectors with large receptive fields, presumably in MST –Medial Superior Temporal- (Tanaka & Saito, 1989), integrate local (smaller receptive fields) signals to build more complex motions (e.g., Braddick, 1993; Morrone, Burr & Vaina, 1995; Sekuler, 1992). In other words, the visual system would encode complex or higher-order motions within the same channels used for unidirectional motion. Thus, functional properties of higher order detectors could thus be predicted from the properties of the local detectors. For example, Sekuler (1992) found that thresholds for looming (expansion) displays could be predicted from combining linearly the thresholds obtained for the lateral (unidirectional) components of the radial motion. On the other hand, there are findings that cast some doubts on the interpretation that the same channels are used for

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distinct kinds of motion. Regan and Beverly showed that expansion and contraction motions are better explained as being independent of one another and, in turn, not represented as a combination of translations (e.g., Beverly and Regan, 1979; Regan & Beverly 1978). Consistent with this view, asymmetries between expansion and contraction have been put forward in the context of a visual search task (Takeuchi, 1997). This author found that searching for expansion was much less affected by set size than was for contraction. This asymmetry can be hardly accounted for a representation of expansion/contraction as a conjunction of local translational detectors. Asymmetries between lateral centrifugal (implied in expansion) and centripetal motion (implied in contraction) have been reported in several studies often yielding conflicting results (e.g., Mateeff, Yakimoff, Hohnsbein, Ehrenstein, Bohdanecky & Radil, 1991, favoring centripetal motion over centrifugal one; Ball & Sekuler, 1980 favoring motion away from the fovea).

In this paper, we concentrate on the differences between expansion and contraction in a detection task (measured by simple reaction time) and in a discrimination task (measured by choice reaction time). Results yielded an asymmetry between both types of radial motion in the two tasks. Data suggest that expansion and contraction rely on different mechanisms irrespective of the task (detection and discrimination). However, instead of regarding these asymmetries as reflecting different integrators for expansion and contraction operating at higher levels, the differences are interpreted as evidence for two distinct low-level stimulus constraints for each type of radial motion. We combine the idea of two different models of local motion processing: velocity-based model (van den Berg and van de Grind, 1989) and distance-based model (Collewijn, 1972) with two different speed-tuned channels in order to better account for the observed asymmetries.

METHOD

Subjects. The same four subjects participated in all conditions. Three of them, including the author, were experienced in psychophysical tasks. Except for the author, participants were naïve with respect to the aim of the experiment. All of them had normal or corrected to normal vision.

Apparatus and Stimuli. The same apparatus was employed in all tasks. Monocular stimuli were displayed in synchrony with the frame rate (100 Hz.) on a 21-inch monitor (Sony GDM F520) with 1280 × 1024 pixels resolution. At 60 cm. the screen subtended 36.92 × 27.69 deg.

There were two types of stimuli created for all the experiments. (1) Lateral motion: a solid sharp-edged white square (40 cd/m²) of 1.8 degs was superimposed on a black background (0.3 cd/m²). The square remained static for a random interval within the range [750 – 1500] ms and then began to move either rightwards or leftwards at one of the following speeds: 0.25, 0.5,

1.0, 2.0, 4.0, 8.0 or 16.0 deg/s. (2) Radial motion: after the same random temporal interval, the square began to expand or contract isotropically. The values used for expansion and contraction rates matched those used for the lateral motion. Since radial motion implies relative motion (e.g. the right edge moves relative to the opposite one), a second square was drawn exactly below the moving one in the lateral motion condition and it was still for the entire presentation. This control seems to be necessary since, as reported by Smeets and Brenner (1994), the RT patterns for absolute and relative translational motion match the ones predicted by the distance and velocity models respectively.

Procedure. For each task (detection-discrimination), each subject was presented with 1120 lateral stimuli (7 speeds \times 2 directions \times 80 repetitions), and with 2240 radial stimuli (7 speeds \times 2 directions \times 160 repetitions). Since we pooled data across the two lateral directions (in preliminary experiments rightward and leftward directions did not produce different patterns), by increasing the number of repetitions we equated the samples across velocities for the three types of compared motion. Speed and direction were randomized from trial to trial. Lateral and radial stimuli were presented in different sessions, but the type of session was assigned at random. All the subjects did the detection task first. In the detection experiment participants were instructed to respond by pressing a button as soon as they saw the square move or increase/decrease regardless of the direction. In the discrimination experiment subjects had to press one of two buttons to indicate the direction (rightwards/leftwards; approach/withdrawal) of the stimuli. Reaction time was measured from the start of the animation.

Data analysis. We fitted to the data a power function of the form:

$$RT = \alpha \cdot v^{-\beta} + T \quad (1)$$

by using the least squares datafit procedure implemented in Scilab software. v is the velocity and T a stimulus independent term. α is a free parameter and β was set to two different values: 1 and 0.5. These different values of the β exponent are the ones that are predicted by two distinct models of motion processing. While in the distance-based model (Collewijn, 1972), RT declines linearly with $1/v$ ($\beta=1$), the velocity-based model (van den Berg and van de Grind, 1989) predicts a linear decreasing with $1/\sqrt{v}$ ($\beta=0.5$). In other words, if a local motion detector gets activated when the stimulus travels a certain distance d regardless of the time it takes to cover d then it predicts an exponent β of 1. On the other hand, if a local motion detector is activated when a stimulus covers a given distance d within a time t , then we expect an exponent of 0.5. These models were initially intended to account for absolute translational motion, however it has been shown that the velocity model can account better for relative motion within the frontal plane (Smeets and Brenner, 1994). Although in radial motion we always have relative motion, it is clear that different exponents might reflect distinct motion mechanisms. In

order to test which model accounted for each type of motion better, we fitted Equation (1) with a constant β , by minimizing a χ^2 merit function (e.g., López-Moliner and Bonnet, 2002; Smeets and Brenner, 1994). Significant values of χ^2 indicate that a given function was not a good description of the data points.

When β is a free parameter then Equation (1) is known as the Piéron function and it has proven to be useful to characterize the same mechanism underlying detection and discrimination perceptual task (Pins and Bonnet 1996). If both detection and discrimination tasks involve the same sensory processes, we expect that the same stimulus dependent parameters (α , β) will account for the data regardless of the task, but a larger stimulus independent term (T) in the discrimination condition suggesting an extra time due to decisional processes.

RESULTS AND DISCUSSION

Detection task.

Figure 1 shows the RT for the detection task as a function of velocity and splitted by motion type. Since results for expansion and contraction resulted in different patterns, they are plotted separately. Mean reaction times for lateral motion and expansion did not significantly differ (paired t-test, $t(6)=-1.317$, $p=0.2359$). Contraction mean RT differed significantly from lateral motion ($t(6)=-3.4$, $p=0.0145$) and expansion ($t(6)=-3.9$, $p=0.0080$). Fittings of Equation (1) with fixed exponent (0.5 and 1.0) showed that while the velocity-based model ($\beta=0.5$) cannot be rejected for either translational ($\chi^2(5)=3.91$, $p=0.56$) or expansion motion ($\chi^2(5)=5.93$, $p=0.31$), it can be for the contraction motion ($\chi^2(5)=17.81$, $p=0.003$). However, when the position-based ($\beta=1$) was fitted to the contraction RT data, it yielded a good fit ($\chi^2(5)=6.91$, $p=0.08$). Additionally, we fitted Piéron functions (β as a free parameter) to the lateral, expansion and contraction data (χ^2 yielded always probabilities higher than 5%, so none fit could be rejected). The fitted parameters, with the 95%-CI, are shown in table 1. The parameters for the lateral motion condition, which implied relative motion, closely matched those reported by Smeets and Brenner (1994). As can be read from figure 1 and table 1, although the fitted parameters for the lateral are more similar to those for the expansion condition and in turn slightly different from those of the contraction one, there is an overlap among the confidence intervals.

The possibility that in the radial motion condition subjects could react to the lateral components of the image motion is a potential shortcoming of the detection task that must be kept in mind. Had the subjects relied on lateral components of the image velocity, the similarities between lateral and expansion could be accounted for by the same mechanism that favors horizontal motion away from the fovea over motion toward the fovea (Ball and Sekuler, 1980). The aim of the discrimination condition was to foster the use of the radial components of the image velocity.

Detection task

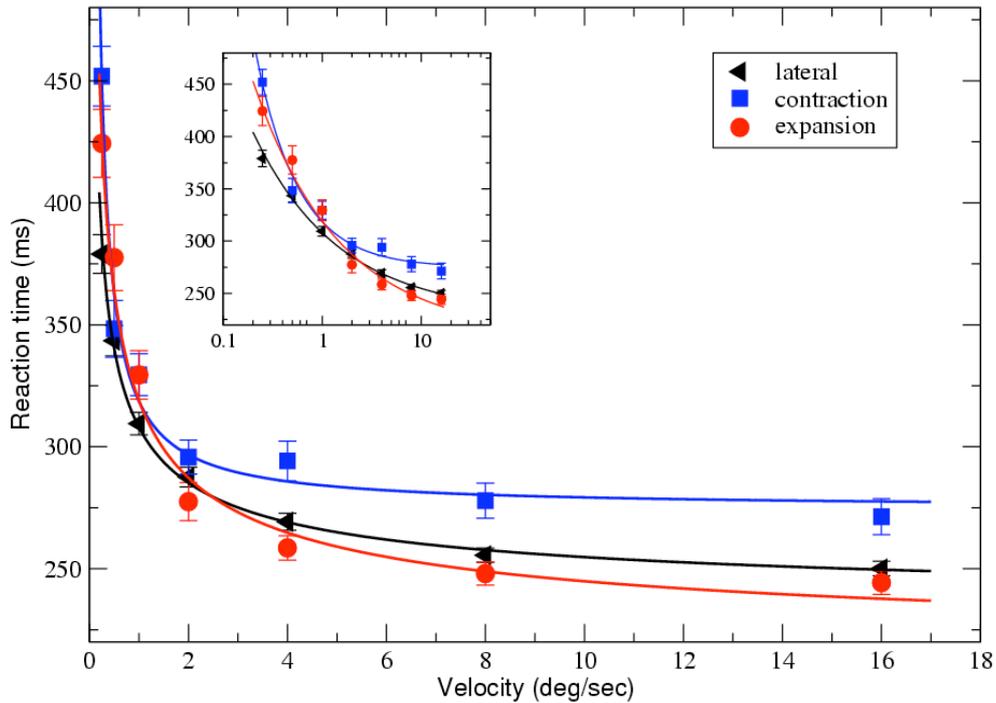


Figure 1. Detection task. Reaction time as a function of velocity split by type of motion. For the sake of clarity, the inset shows the same data using a log-lin plot. The solid lines show the fits of the models that accounted for the data better: the velocity model for the lateral and expansion and the distance model for contraction.

Table 1.

Type of motion	Detection			Discrimination		
	\square	\square	T	\square	\square	T
Lateral 95%-CI	92.43 69.7-115.2	0.41 0.3-0.51	217 198 - 237	200.6 91.8-146.3	0.19 0.31-0.51	169 67 - 271
Expansion 95%-CI	117.3 35.4-199	0.47 0.15-0.80	204 136-273	91.8 13.2-170.4	0.68 0.18-1.17	313 253 - 372
Contraction 95%-CI	42.45 10-75	1.01 0.5-1.53	275 253- 298	33 14.6-51.4	1.3 0.92-1.7	368 355 - 382

Discrimination task

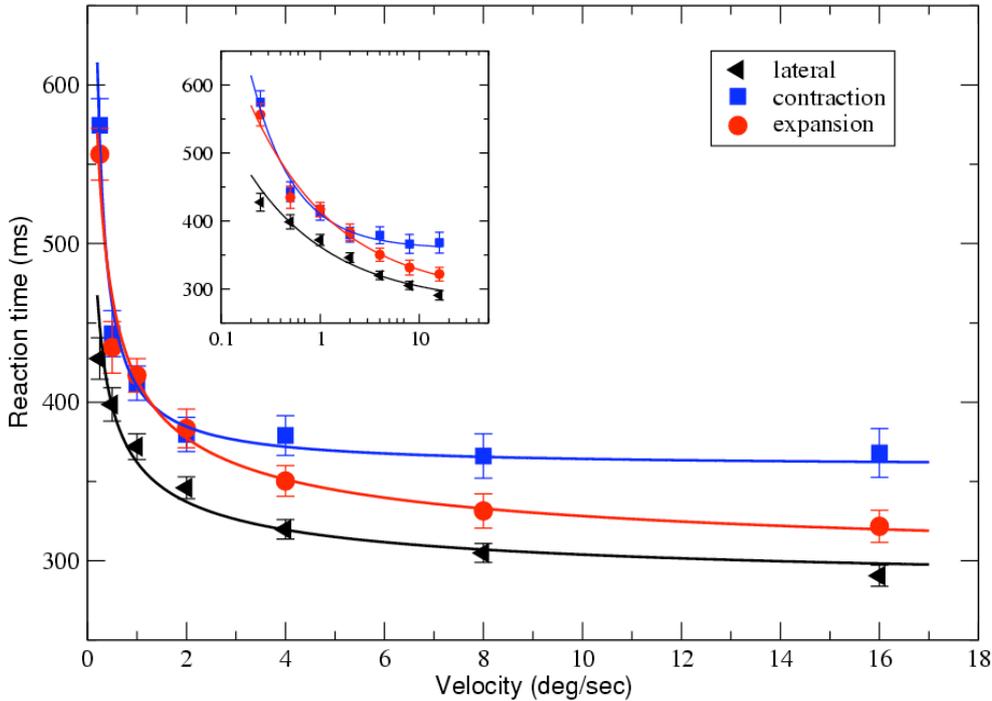


Figure 2. Discrimination task. Reaction time as a function of velocity split by type of motion. As in figure 1, we plot the log-lin plot of the same data. The solid lines show the fits of the models that accounted for the data better: the velocity model for the lateral and expansion and the distance model for contraction.

Discrimination task.

Again, velocity model explains better lateral ($\chi^2(5)=3.97$, $p=0.55$) and expansion ($\chi^2(5)=8.2$, $p=0.14$) motions, while the position based cannot be rejected for the contraction motion ($\chi^2(5)=9.08$, $p=0.11$). In Figure 2 we plot the RT data for the three conditions and the fits of the model that better account for each set of data. Like in the detection task, we also fitted Piéron functions to every data set. The parameters of these fits are shown in table 1. Unlike the detection experiment, mean reaction time for lateral motion is significantly lower than RT for expansion ($p<0.05$) and contraction ($p<0.05$). Mean expansion RT is lower than that of contraction ($p<0.05$). Despite the difference in the overall mean RT, 95%-CI of parameter estimates for lateral and expansion remarkably overlap, and differed from those obtained for contraction.

CONCLUSIONS

The similarity of reaction times between the lateral and expansion motions within the detection task are difficult to accommodate for a two-stage model of motion processing (e.g. Morrone et al., 1995). If we assume that radial motion is built after encoding the lateral components, we would expect longer times for the radial condition than for the lateral one. How can this similarity then be explained? We think that a reasonable explanation, as stated above, is that subjects were not relying on the radial components but rather on the lateral ones in the detection task. As long as they have to respond to motion onset, irrespective of its type, detection of the lateral components is enough to fulfill the requirements of the task. This seems a more parsimonious explanation; especially if we take into account that when participants were forced to rely on the radial components (e.g., discriminating between expansion and contraction) this similarity dissipates.

One intriguing similarity holds between expansion and lateral motion in both tasks. The velocity-model accounts better for both kinds of motion than the distance model. Since both lateral and expansion implied centrifugal motion, it might likely be the case that the same channels were stimulated while the contraction motion (centripetal motion) was tapping a distinct channel. Much evidence has been reported to support the idea that image speed information is segregated in two different (slow and fast) channels (e.g., Gegenfurtner & Hawken, 1996; van der Smagt, Verstraten, & van de Grind, 1999). Furthermore, van de Grind, van Hof, van der Smagt, & Verstraten (2001) have raised recently the possibility that magno and parvo anatomical channels underpin these two speed-tuned psychophysical channels. So, while the magno stream would be devoted to fast speeds (> 1 deg/sec), the parvo pathway would process low speed signals. If we assume this possibility it is not unlikely that the two distinct radial motions (expansion and contraction) were stimulating the fast and slow channels respectively. Note that the distance-based model, which accounts for the contraction data better than the velocity model, allows for a wider reaction time range when the speed is slow (e.g., the RT curve is steeper for lower speeds).

This interpretation would cast some doubts on the necessity of independent higher order detectors for expansion and contraction, since differences at the low-level processing can also provide an explanation for differences between expansion and contraction. However, as long as our design does not allow us to put expansion and contraction motions in correspondence with parvo and magno streams unequivocally, further research will be needed in order to disentangle this issue.

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