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REACTION TIME TO MOTION ONSET RELATIVE TO BACKGROUND MOTION

Master`s thesis

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Abstract

The dependency of target motion detection on the velocity and direction of the background motion was investigated using a disc (either 8.26º or 1.2º in diameter) filled with a sinusoidal grating as a stimulus and by varying the gap (either 1.2º or 0.03º) between the target area and background grating. Background moving in the same direction to the target prolonged RT-s to target motion onset. Background effects were stronger for the small target. Also in case of small target area the background moving in the opposite direction prolonged the RT-s (in the conditions with gap 0.03º). In the control experiment subjects had to discriminate the direction of the target area and made more mistakes when both (the target and the background) were moving < 1.0 º/s.

Keywords: Relative motion, velocity, motion direction, background motion, reaction time.

Running head: Reaction time to motion onset

Kokkuvõte

Liikumise alguse avastamine sõltuvalt tausta liikumisest.

Käesolevas töös uuriti testala liikumise alguse avastamist sõltuvalt tausta liikumise kiirusest ning suunast, kasutades stiimulina siinusvõret (testala diameeter: 8.26º või 1.2º) ning varieerides vahemaad testala ja tausta vahel (kas 1.2º või 0.03º). Samasuunaline tausta liikumine pikendas reaktsiooniaega testala liikumise alguse avastamisele. Tausta liikumise halvendav mõju tajumisele oli tugevam väikese testala puhul. Väikese testala puhul (kui vahemaa kahe ala vahel oli 0.03º) pikendas ka vastassuunaline tausta liikumine reaktsiooniaegu. Kontrollkatses pidid katseisikud eristama testala liikumise suunda ning tegid rohkem vigu, kui testala ja taust liikusid mõlemad alla 1.0 º/s.

Märksõnad: Relatiivne liikumine, liikumiskiirus, liikumissuund, tausta liikumine, reaktsiooniaeg.

Läbiv pealkiri: Reaktsiooniaeg liikumise avastamisele

Introduction

In order to cope with the complexity of visual perception researchers have tried to simplify the task by studying single visual attributes in isolation. However, very soon it became obvious that the perceived qualities of visual attributes depend on the presence of visual attributes in the proximate or even distant neigbourhood. For example, the perceived color or brightness of some area changes the perceived color of the surrounding areas. Similar contrast effects were discovered for almost all visual attributes such as orientation, density, and depth. Analogous contrast effect in motion perception (Holmgren, 1973) was discovered relatively late mainly because motion as such can be defined only in relative terms: its is always necessary to specify a frame of reference in which motion is described.

It is possible to talk about two stages of computations in motion perception-movement encoding and decisions (Dzhafarov, Sekuler & Allik, 1993). This parallels roughly the distinction between local and global motion perception. Motion encoding is a general task-independent computation that provides an internal representation of the kinematic properties of the visual scene when information from retinal input is encoded into an activation pattern of quasi-neuronal network of primary Reichardt-type motion detectors These detectors are not tuned to any one distance, speed or temporal frequency. Instead, there is a potential connection between every detectable position and every detectable time in some reasonable limits. This activation pattern then becomes input for task-specific computations in the detection phase. In that phase, weighted average of activation pattern is calculated using the square of distance as a weight. The distinction between encoding and decision can explain the disparity between different tasks that our perceptual system faces- the information that is available for one type of computation may not be available for another type of computation (Kreegipuu, 2004). Different tasks may rely on different portion of information represented by the network of elementary motion encoders. This means that the performance in a particular motion-related task can not be reduced to the properties of elementary encoding network. For complex representations of the visual field local motion energy mechanisms serve as an input for global motion, which is the perceived direction of a dynamic input when that direction is the result of a combination of many individual motion signals within the stimulus (Cropper, 2001).

Usually there are many objects moving at the same time with different speeds and directions in the visual field and perceptual decisions are made based on the relative motion where dynamic input from different locations is considered. Cues for motion perception can be discriminated into absolute cues (sometimes referred to as subject-relative cues, e.g in Wallach, O`Leary & McMahon, 1982) that provide information regarding the motion of the object relative to the observer, and relative cues (sometimes referred to as object-relative cues e.g in Wallach et al., 1982) regarding the motion of objects relative to each other (Gogel & McNulty, 1983). This relativity of perceived motion is evident also in velocity perception (in assessing the changes in velocity of different objects in the visual field). The idea that our perception of motion is not simply dependent on absolute velocities of isolated points was proposed by Karl Duncker already in 1929 with his work on induced motion (Holmgren, 1973; Tynan & Sekuler, 1975; Nakayama & Tyler, 1978; Becklen & Wallach, 1985), which is also referred to as simultaneous motion contrast (e.g. Murakami & Shimojo, 1996) or heterokinesis (Nawrot & Sekuler, 1990). The most common example of this phenomenon is the case where physically stationary object is perceived to move in the direction opposite to another object which is moving near the former or surrounding it. An opposit result where a stationary object is perceived to move in the same direction as an inducer is a phenomenon of motion capture or assimilation (Chang & Julesz, 1984; Murakami, 1998; Ido, Ohtani & Ejima, 2000), also referred to as homokinesis (Nawrot & Sekuler, 1990). Psychophysical and electrophysical studies have shown that surround moving in the same direction as the target decreases neuronal activity and behavioural sensitivity (Ido et al., 2000; Nawrot & Sekuler, 1990).

One of the explanations of induced motion or motion contrast has been the concept of the frame of reference, with respect to which the motion should be described. In this view the perceived position of the stationary object (a small dot for example) is referenced to the coordinate system of the frame surrounding it, not the whole room. The essence of the frame of reference theories is the contrast of motion - for example when center and surround of the visual display move in the same direction, the increase in surround velocity should decrease the perceived speed of the center (or an object); when center and surround move in the opposite direction, the increase of the surround velocity should increase the perceived speed of the centre. It has been argued, though, that these simple predictions are not entirely valid. Results from Tynan and Sekuler (1975) show that with increasing surround speeds the perceived speed of the center first decreases and then returns to baseline. The apparent center speed reached a minimum at about the point where surround and center are moving at the same speed.

The other view supports the idea of neural inhibition between mechanisms sensitive to motion in the centre and mechanisms sensitive to motion in the surround (a centre-surround antagonism) (Holmgren, 1973; Tynan & Sekuler, 1975; Murakami & Shimojo, 1996; Paffen, te Pas, Kanai, van der Smagt & Verstraten, 2004). Murakami and Shimojo have called this directionally antagonistic unit that is inhibited by moving stimuli in the surround a „motion contrast detector" (1996). They have found that when the overall size of the stimulus is decreased, induced motion could change to motion capture and it is suggested that a population of detectors is distributed around a certain stimulus size at each eccentricity (Murakami & Shimojo, 1993). A stimulus of the optimal size results in a percept due to relative motion processing (induced motion). A smaller stimulus, where both the inducer and the target (induced stimulus) are within the centre field, results in another percept due to nonselective pooling of motion information (motion capture). Physiological findings have shown that the response to an optimally oriented stimulus presented to a neuron`s classical receptive field in primary visual cortex can be inhibited by presenting a stimulus with the same orientation to its surround. The centre-surround antagonistic interactions have also been described in motion sensitive neurons in middle temporal area (MT) (Treue, Hol & Rauber, 2000; Paffen et al., 2004).

When explaining changes in perceived motion another phenomenon, namely crowding (also referred to as spatial interference or local contour interaction) should be taken under consideration (Bex, Dakin & Simmers, 2003; van den Berg, Roerdink & Cornelissen, 2007; Kyllingsbæk, Valla, Vanrie & Bundesen, 2007). Electrophysical and behavioural studies have shown that the classical receptive fields of early visual mechanisms are selective for stimulus attributes such as spatial frequency, orientation and direction of motion (Bex & Dakin, 2005). To gain functional information about objects and their movements, it is clear that such local representations must be integrated across visual field. Local motion-energy mechanisms are functionally similar to Reichardt detectors and serve as an input to hierarchical models concerned with combining local motion signals into complex representations of the visual environment (Dzhafarov et al., 1993; van den Berg & van de Grind, 1989). While pooling of the local signals is therefore necessary for the perception of global structure, studies have shown that information about component structure can be degraded in the process of image integration (Bex & Dakin, 2005). These crowding effects are maximal when the stimulus orientation, spatial frequency and spatial structure of the target and surrounding stimuli are similar (Bex et al., 2003; Bex & Dakin, 2005). Bex et al. (2003 and 2005) and van den Berg, et al. (2007) found that in line with many previous studies, acuity decreased and crowding increased with eccentricity (critical spacings are roughly half the eccentricity). Acuity also decreased for moving targets, but the absolute size of crowding zones remained relatively invariant of speed at each eccentricity. Crowding is sometimes considered to be a masking phenomenon (Chung, Levi & Legge, 2001), but it could only be so in the foveal vision, because for example, in the peripheral visual field crowding effects are equal for stimuli that are of either same or opposite contrast polarity and it rules out masking effects (Bex et al., 2003). Crowding differs from pattern masking in that target and mask signal do not necessarily have to overlap to have an effect (van den Berg, Roerdink & Cornelissen, 2007).

Returning to the topic of motion contrast effect or assimilation, the magnitude of these effects in motion perception depends on various stimulus parameters. First, there is an inverse relationship: the effect that the two areas (or objects) have on each other decreases when the distance between them increases. More specifically the adjacency principle states that the contribution of relative cues of motion to the perception of motion increases as the separation of the objects decreases either in the frontoparallel plane or in depth. (Gogel & Tietz, 1976; Becklen & Wallach, 1985). Second parameter that is effectively influencing the magnitude of contrast effect is the velocity of the inducing stimulus (in case of the stationary target) or the velocity of both areas (target and surround). To be more specific, the relative motion between the centre stimulus (the target) and surrounding stimulus (the background) (Becklen & Wallach, 1985). When background velocity increases (or if the inducer is oscillating - the oscillating frequency increases) contrast effect decreases. Third variable to consider is the direction of motion if the two areas (centre and surround; object and background) are both moving. Tynan and Sekuler found that when the centre and surround are moving in the same direction and the surround velocity increases, the perceived velocity of the centre first decreases and then increases; when the centre and surround are moving in opposite directions, the increase in surround velocity results in the increase of perceived velocity of the center (Tynan & Sekuler, 1975). This assimilation-type phenomenon has also been found by Chang and Julesz (1984) who reported that at limited range in space test pattern was biased towards the direction of inducing stripes. Fourth, the effect of stimulus size is important (Murakami & Shimojo, 1996). Quite a few studies have reported that assimilation is confined to a relatively restricted region- under 15' in the work of Chang and Julesz (1984) and distances about 3 times larger (depending on stimulus velocity) in the work of Nawrot & Sekuler (1990).

In the present study detection of target motion onset dependent on background motion is examined in the light of the previous reports on motion contrast and motion capture phenomenon. Surprisingly, there are no studies in which the observer's ability to detect motion onset was examined dependent on motion in surrounding areas. Due to its reliability reaction time (RT) to motion onset is an ideal model for studying the influence of the background motion on the perception of the target motion. All the above listed parameters (size of the target stimulus, velocities of stimulus and background, distance between stimulus and background and direction of motion) can be easily manipulated in order to reveal interactions between the target and background areas.

Method

Participants. Six observers (1 male and 5 females, mean age 20.6±1.9 years), one of them well-trained and five naïve conserning the purposes of this study, took part in all series of the experiment. They all had normal vision.

Apparatus. Stimuli were generated with Cambridge *ViSaGe* visual stimulus generator (*Cambridge Research Systems Ltd.*) and presented on the monitor screen Mitsubishi Diamond Pro 2070SB (frame rate 140Hz) which from the viewing distance of 90 cm subtended 27.6 º in width and 20.5º in height.

Stimuli. The screen was filled with sinusoidal distribution of luminance which varied in the horizontal direction. The luminance of the most dim location was 0.13 cd/m^2,of the brightest location 128.2 cd/m^2. The spatial frequency of the vertical grating was 0.65 c/º. Around the central fixation point a round area was separated by a gap either 0.03º (i.e., “no gap” [1]) or 1.2º (i.e., “wide gap”), forming a target area. The target area had a diameter of 8.26º (i.e., “large”) or 1.2º (i.e., “small”). The area outside the gap served as background. Each trial started with background and target appearing on the screen and after a random interval from 800 to 1200 ms the background started to move (if the background velocity was not 0º/s) horizontally either left or right. After a stimulus-onset asynchrony of 0 (i.e., simultaneous onsets), 500 or 1000 ms target area started moving horizontally rightwards. Background velocities were 0º/s, 0.4º/s , 0.8º/s , 1.6º/s or 3.0º/s. Target velocities were 0.4º/s , 0.6 º/s, 0.8º/s , 1.0 º/s or 1.6º/s. Between trials a neutral (grey) uniform display (with the luminance 65.4 cd/m^2) was shown for 1000 ms.

Procedure. The subjects sat 90 cm from the monitor screen in a semi-darkened room. The instruction was to keep the eyes on the fixation point and react to the motion onset of the target area by pressing a corresponding button on the response box. Observer`s response ended a trial. One experimental session consisted of 4x150 trials. There were 4 different experimental sessions for each of the observers: 1) “large” target area and “wide” gap, 2) “small” target area and no gap, 3) “large” target area and no gap, 4) “small” target area and “wide” gap.

Control experiment. In addition a control experiment was carried out. The stimuli used were the same as in previous 4 experimental series with the following differences: target area was always 1.2º (i.e “small”), gap between target area and background was always 0.03º (i.e “no gap”), only target velocities of 0.4 º/s and 0.8º/s were used, target motion was horizontally either left or rightwards (while in previous series it was only rightwards). The instruction in the control experiment was to keep the eyes on the fixation point and react to the motion onset and direction of the target area by pressing a corresponding (left/right) button on the response box. One trial lasted for 3000 ms and observer`s response did not end the trial. Each observer attended one experimental session that included 4x120 trials.

[1] A term *no gap* is used, because a gap this narrow functions as a contour of the target area

Results and discussion

The first analysis is conserned with the size of the target area. It could be expected that a small target area (compared to the large target area) is more vulnerable to the influence of the background motion.

Large target area.

RT-s over 100 ms and under 1000 ms were included in the analyses. *One-Way* ANOVA revealed significant effect of target velocity [$F(4,6658)=166.74$, $p<.0001$] and direction (background moving either in the same or opposite horizontal direction to the target or background not moving) [$F(2,6660)=40.06$, $p<.0001$], but an insignificant effect of the gap between target and background areas [$F(1,6661)=3.66$, $p=.056$]. Background velocity had a significant effect on RT-s only in the case of target velocities under 1.0º/s: for 0.4 º/s [$F(8,1310)=5.55$, $p<.0001$]; for 0.6º/s [$F(8,1307)=3.63$, $p=.00035$] and for 0.8º/s [$F(8,1311)=4.25$, $p=.00005$].

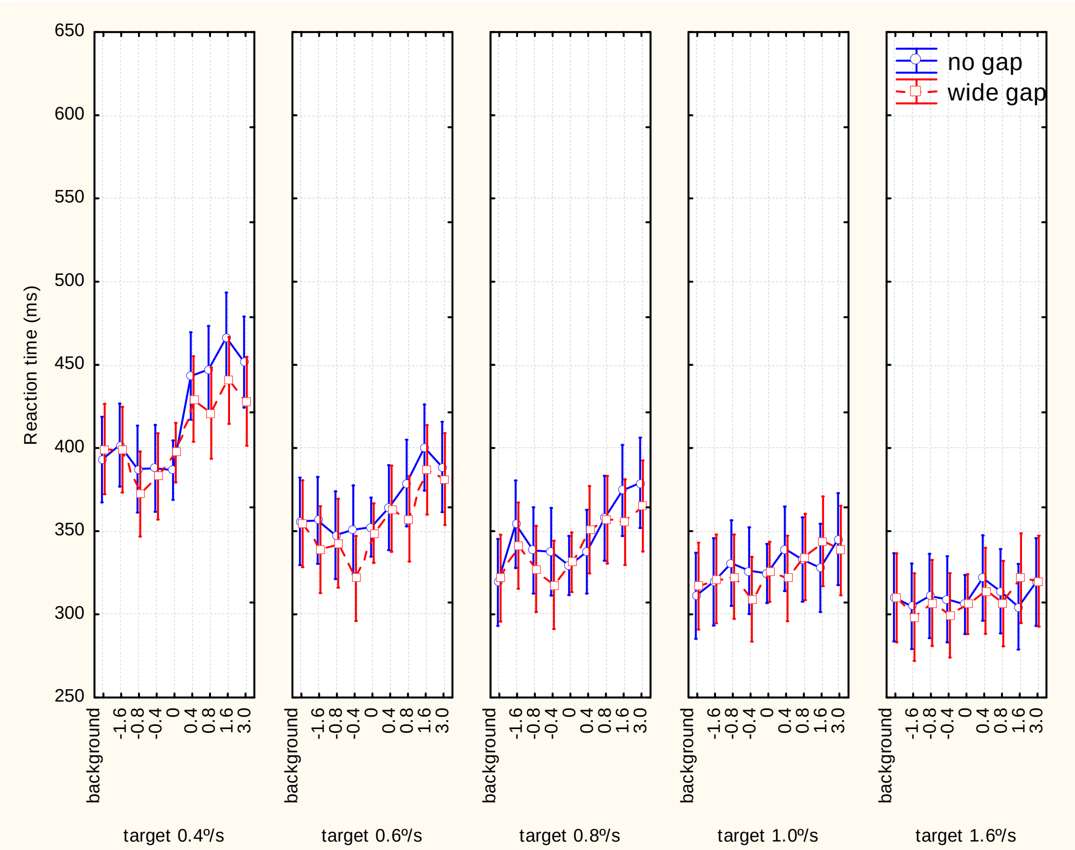

Figure 1. The mean reaction times (with 95% confidence limits) to target motion onset on different velocity conditions and gap/no gap between target and background. Target area is 8.26º in diameter

Direction of the background (either same or opposite to the target area) was not significant when target velocity was 1.6º/s, showing (consistent also with the results of the effect of background velocity) that when the target is moving “fast” the movement in the surrounding areas does not affect the detection of target motion onset. These results are shown in Figure 1 (on the previous page).

Although the effect of the gap between target and background areas was not significant (either analysed over all the data or separately over different target velocity conditions) *factorial* ANOVA was conducted on both gap conditions (no gap vs. wide gap) separately to find any difference between those conditions. The interaction between target velocity and background movement direction was significant with no gap (i.e 0.03º) [$F(8,3338)=3.01$, $p=.0023$] and insignificant when the gap was wide (i.e 1.2º) [$F(8,3295)=0.97$, $p=.46$]. The main difference occurs when the background moves in the same direction as the target, where on the lowest target velocity (0.4º/s) mean RT is about 20 ms longer when there is no gap. Otherwise the tendencies to detect motion onset were similar on both conditions. Interactions between target and background velocities were insignificant also in both conditions: $F(32,2749)=0.86$, $p=.68$ for no gap; $F(32,3279)=0.4$, $p=.99$ for wide gap.

Small target area.

Again RT-s under 100 ms and over 1000 ms were excluded from the analyses. All the variables in *One-Way* ANOVA analyses had significant effects on RT-s: target velocity [$F(4,6438)=117.83$, $p<.0001$], background velocity [$F(4,6434)=17.08$, $p<.0001$], direction of the background (either in the same or opposite horizontal direction to the target or background not moving) [$F(2,6440)=33.58$, $p<.0001$] and gap between target and background areas (either 0.03º or 1.2º) [$F(1,6441)=251.01$, $p<.0001$]. *Factorial* ANOVA showed a significant interaction between target and background velocities when there was no gap between the two areas [$F(32,3234)=2.19$, $p=.00013$], but insignificant interaction [$F(32,3377)=0.76$, $p=.83$] with a “wide” gap. The results are taken together in Figure 2. It is clear that when the target area is “small” (compared to the target area with the diameter of 8.26º) and the gap between this and the background is “wide” (i.e. 1.2º) there is no significant effect of the background velocity [$F(8,3280)=0.88$, $p=.525$] or direction [$F(2,3286)=1.4$, $p=.246$]. When there is no gap (i.e 0.03º which subjectively is just a contour) the direction of the background is significant [$F(2,3151)=49.67$, $p<.0001$], especially on lower target velocities. Background moving in the same direction as the target always prolonges the RT-s to target motion onset. But surprisingly enough and especially on low target velocities the background moving in the opposite direction to the target also prolongs the RT-s.

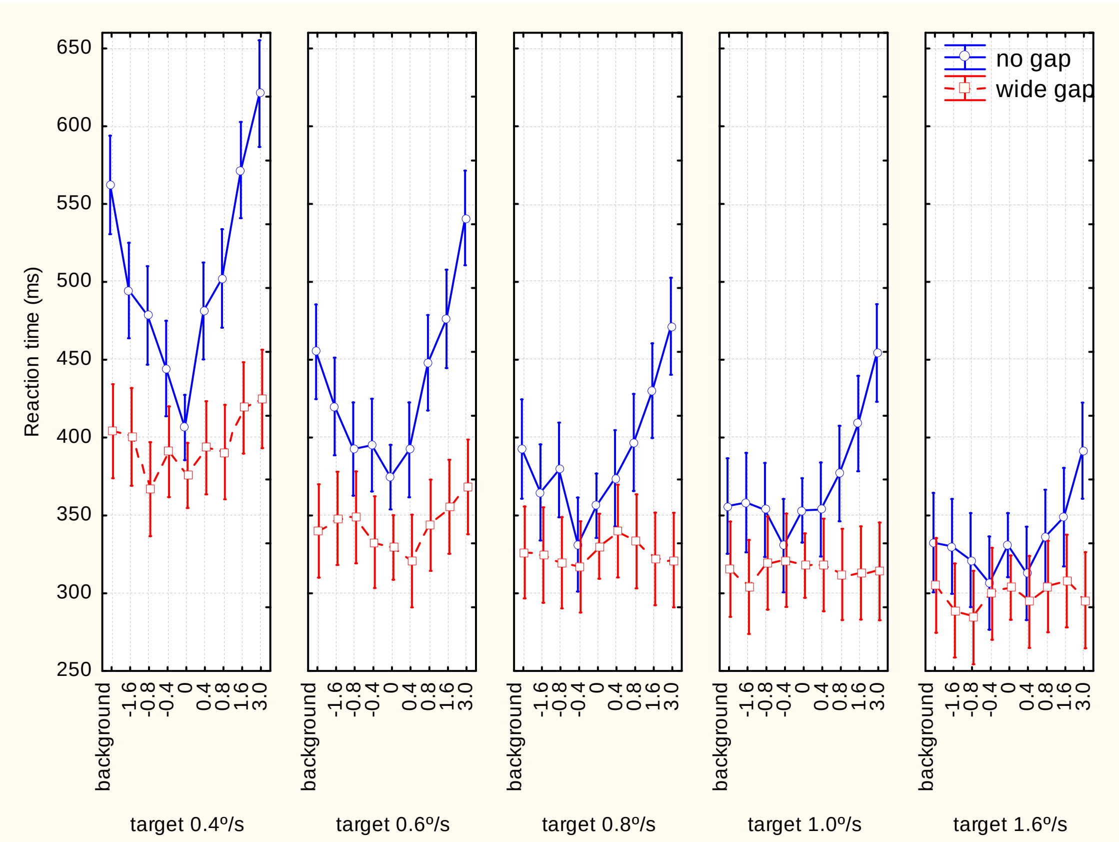

Figure 2. The mean reaction times (with 95% confidence limits) to target motion onset on different velocity conditions and gap between target and background. Target area is 1.2° in diameter.

When the two conditions with different target area sizes are compared, two conclusions can be drawn.

(1) First, with the larger target area the effect of the background is modest and does not differ much if the gap between target and background changes, while when the target area is small (with a diameter of 1.2°) there is a significant difference between the two gap conditions. This shows that the moving background affects detection of target motion onset the most with small targets that are close to the background (gap of 0.03° subjectively is just a contour).

(2) Second, it is interesting that while with the large target area (with a diameter of 8.26°) with lower target velocities background moving in the same direction

prolonged the detection of target motion onset and the same tendencies were seen with the small target area, in case of small target area the background moving in the opposite direction also prolonged the RT-s (in the conditions with no gap).

Considering the previous results that the reaction time curves to target velocity decrease progressively with the increase if target velocity (as illustrated on Figure 3 for the condition of small target area with no gap; the details behind this choise of conditions is revealed in the following text) it is possible to assume that the background motion affects the target motion in a way as its apparent velocity has decreased and in the result of that it takes more time to notice motion onset. It is well documented that RT-s to motion onset can be decomposed into two components: velocity dependent component and residual time (Dzhafarov et al., 1993).

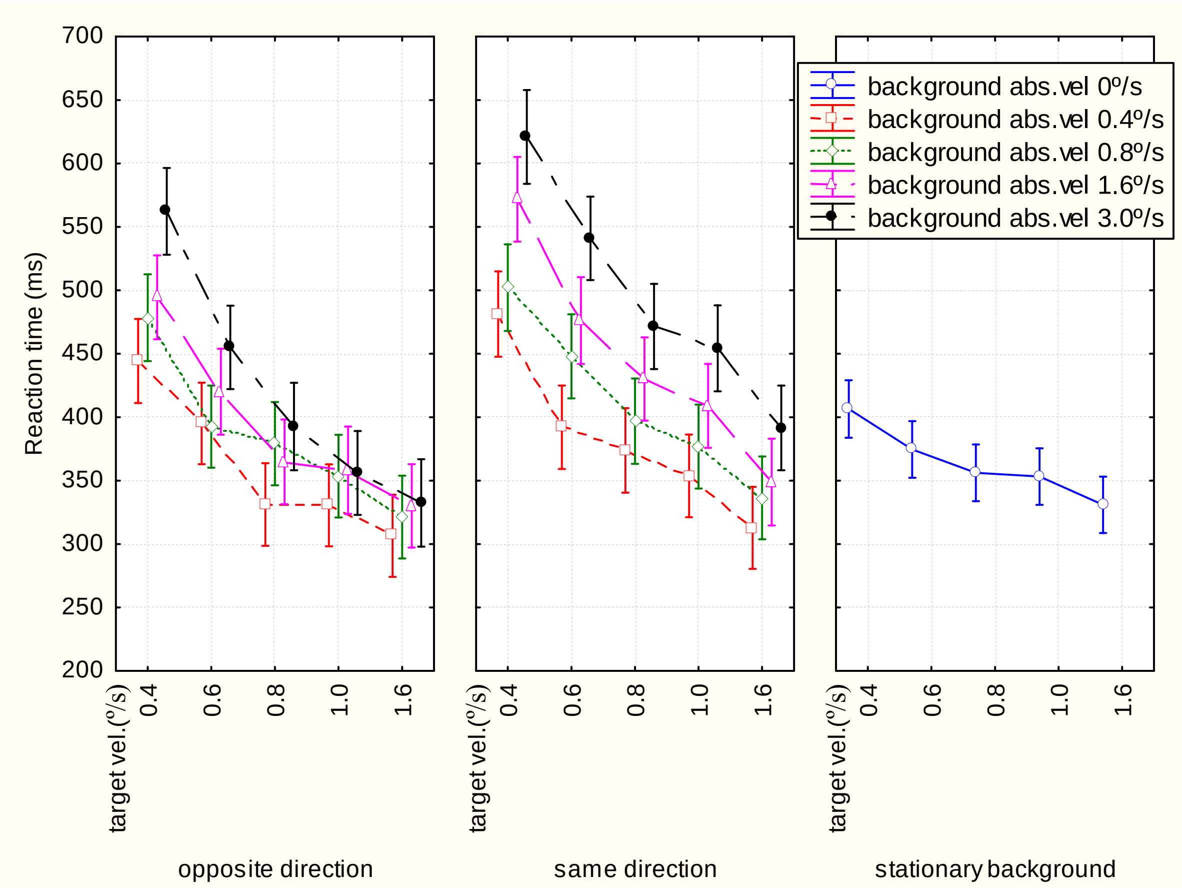

Figure 3. The mean reaction times (with 95% confidence limits) to target motion onset on different velocity conditions and directions. Target area is 1.2° in diameter. No gap between target and background. Note that background velocity is given in absolute values.

According to the kinematic energy model the manual RT to motion onset is a negative exponent power function of stimulus velocity V with exponent close to –2/3: RT =

$RT_0 + c^* V^{-2/3}$. If the background motion affects the perceived velocity, the best approximation must be achieved not with the actual phycical velocity *V*, but with a perceived velocity $V^* = V + \Delta V$, where ΔV is the subjective change in the target velocity. Thus, the RT depends on the residual RT_0 and the coefficient of proportionality *c* that describes perceptual sensitivity to stimuli moving with different perceived velocities: $RT_0 + c^*(V + \Delta V)^{-2/3}$. (for the explanation see Allik & Dzhafarov, 1984; Dzhafarov et al., 1993). An approximation was conducted on data averaged across all subjects as individual data showed similar tendencies. The coefficient of proportionality *c* was assumed to be equal for motion onset as we expected the sensitivity to motion velocity would not change with the background velocity. In case of the „wide" gap (1.2º) there was no convergence either when the target was 8.26º or 1.2º in diameter as was expected seeing the results described above (Figures 1 and 2). For the condition of large target (with a diameter of 8.26º) with no gap the approximation was conducted, but it accounted only for 84.57% of the variance, which could be expected since there was no apparent shift in the velocities (figure 1). Considering that, only the approximation results for the condition of no gap (0.03º) for small target area size (1.2º in diameter) are presented here (Figure 4 and Table 1).

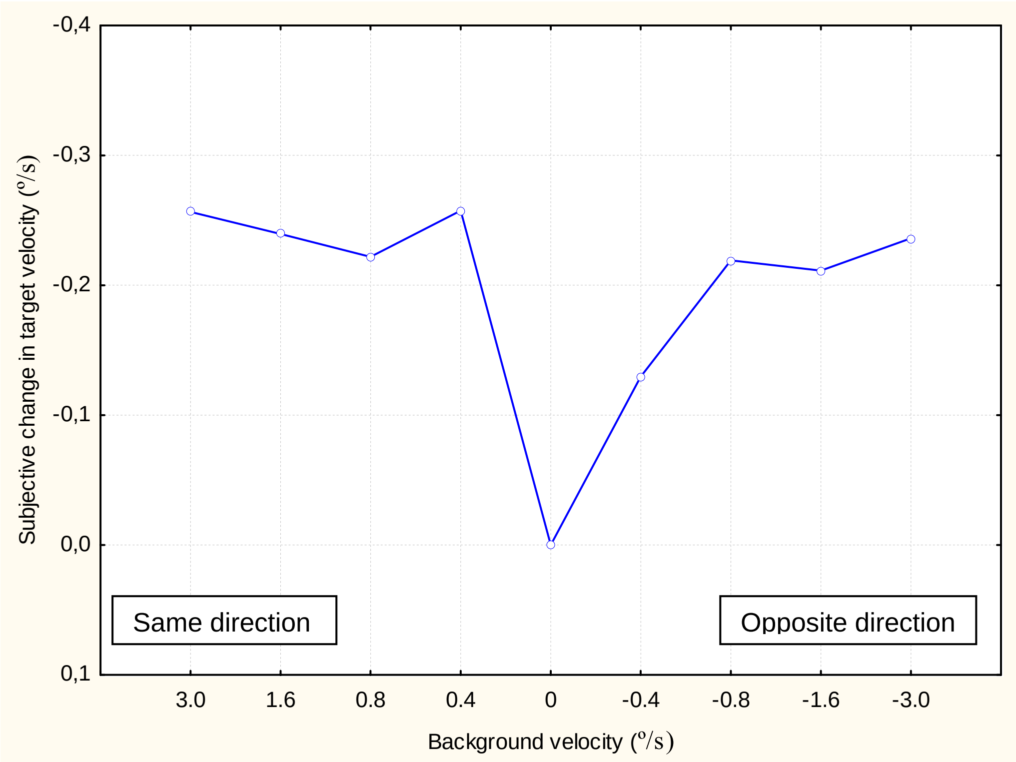

Figure 4. Subjective change in perceived target velocity ΔV. Averaged RT data for target motion onset when the gap between target area and background was 0.03º (i.e. no gap). Continuous curves show the best fitting negative exponential power function ($RT = RT_0 + c^*$ $V^{-2/3}$) for the small target area with common c = 80,7 .

	RT_0	RT_1 (-0.4º/s)	RT_2 (0.4º/s)	RT_3 (-0.8º/s)	RT_4 (0.8º/s)	RT_5 (-1.6º/s)	RT_6 (1.6º/s)	RT_7 (-3º/s)	RT_8 (3º/s)
Estimate	270.94	221.62	217.77	213.23	231.68	221.26	263.59	203.26	261.83
Std.Err.	28.94	24.95	28.44	26.52	27.16	26.77	27.15	27.63	29.28
t(27)	9.36	8.88	7.66	8.04	8.53	8.26	9.71	7.36	8.94

Table 1. Estimated RT values for the different background velocities (º/s). For all conditions p < .00001.

The best fit was found with c = 80.7, which is slightly bigger than the coefficent of proportionality in Kreegipuu & Allik, 2007 (their approximation results gave c = 64.2, but their stimulus did not have a center-surround discrimination i.e there was no background to affect the RT-s). The approximation accounts for 91.74% of the variance. In such approximation, it is possible to quantify the potential change in perceived velocity of the target area and it shows that due to background it always subjectively slows down. The subjective decrease in target's velocity is bigger when the background moves in target's direction. It means that for a target velocity 1.0º/s, it is actually perceived as 0.75º/s in case of fast (3.0º/s) same-direction background motion and as 0.87º/s in case of slow (0.4º/s) background motion into opposite direction.

When analysing RT data the mistakes[2] that are made when one detects motion onset could implicate the existence of induced motion in the opposite direction, i.e the incorrect responses from the perspective of physics could be „correct" in the perspective of perception (by correct it is meant that apparent motion or change in motion is perceived). RT-s < 100 ms were examined as mistakes and the percentage of these mistakes was highest in the condition of small target area with no gap (7,24%). What could be the explanation of these mistakes and do they show the phenomenon of motion capture or contrast? Would there have been any differences if in the original stimulus configuration we had allowed the target to move in both horizontal directions (as did the background)? These questions led us to further investigate the interactions between target and background velocity and direction in the control experiment.

[2] RT-s < 100 ms are considered as mistakes here.

Control experiment.

The reasoning behind choosing only two target velocities (0.4°/s and 0.8°/s) from the previous set of five for the control experiment was to choose only the conditions that gave results that differed from the scope of all data. To control that the subjects do not make the decisions about target motion onset based on their previous knowledge about the movement direction of the target (since the target always moved horizontally rightwards on the screen in the previous experimental sessions), target motion was either horizontally left or right (as was background motion) and the subjects had to discriminate the direction. First, approximately ¼ of the answers made about the direction of target motion were wrong: 23.32% from the whole set of 2882 responses. Since we used RT values between 100 and 1000 ms in our previous data analyses, the data in the control experiment was divided into two groups: RT-s under 100 ms and RT-s over 100 ms. Results in Table 2 show the numbers and percentages of correct and incorrect answers to motion direction detecting.

	No. of correct answers	*% of correct answers*	*No. of incorrect answers*	*% of incorrect answers*
RT < 100 ms	132	4.58%	123	4.27%
RT > 100 ms	2078	72.1%	549	19.05%

Table 2. Numbers and percentages of correct and incorrect answers made about the target motion direction for RT<100 ms and RT>100 ms. Sum of responses = 2882.

Using *One-way* and *Factorial* ANOVA following effects on RT-s were found: significant effect of background velocity [$F(8,2792)=4.06$, $p<.0001$]; significant effect of target velocity [$F(3,2797)=34.4$, $p<.0001$]; significant effect of direction (the two areas moving either in the same or in the opposite horizontal direction or background not moving) [$F(2,2798)=5.86$, $p=.002$]; insignificant interaction between target and background velocities [$F(24,2765)=1.4$, $p=.108$]; insignificant interaction between target velocity and direction (the two areas moving either in the same or in the opposite horizontal direction or background not moving) [$F(6,2789)=0.68$, $p=.663$]. Figure 5 shows the RT-s to motion onset by different directions.

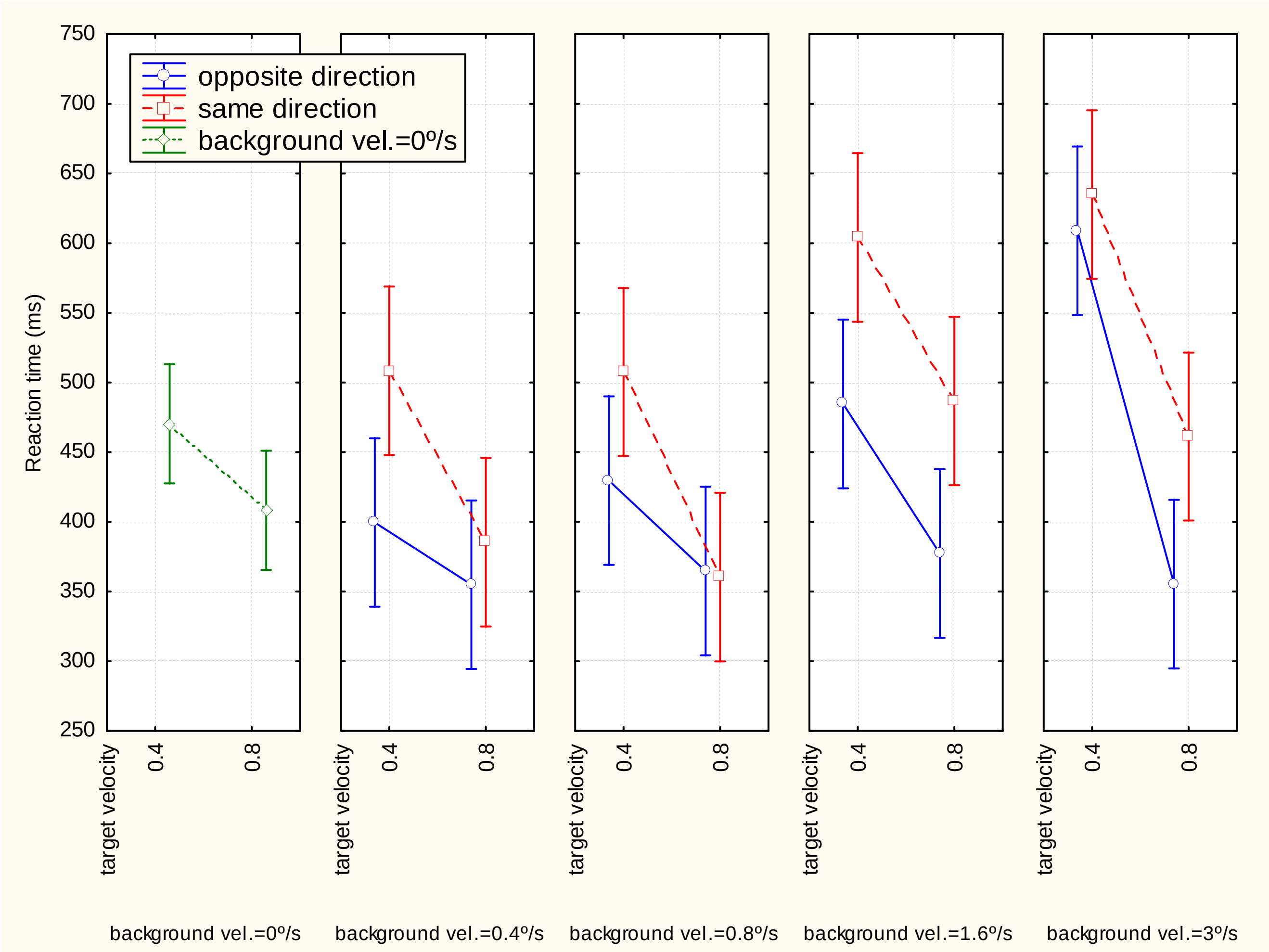

Figure 5. The mean reaction times (with 95% confidence limits) to target motion onset on different velocity conditions (°/s) *and direction conditions. Note: the velocity values are absolute.*

Since subjects had to respond direction-specifically i.e. determine in which direction the target area moved (horizontally right or left) the responses were coded into „right" and „wrong" answers. The effects on the response accuracy were following: insignificant effect of the background velocity [$F(8,2792)=0.58$, $p=.787$]; significant effect of the target area velocity [$F(3,2797)=2.8$, $p=.034$]; significant effect of direction [$F(2,2798)=17.1$, $p<.0001$]. The interaction between background and target velocities was significant [$F(24,2765)=2.2$, $p=.0009$], the interaction between target velocity and direction (the two areas moving either in the same or in the opposite horizontal direction or background not moving) was insignificant [$F(6,2789)=0.24$, $p=.96$] (Figure 6).

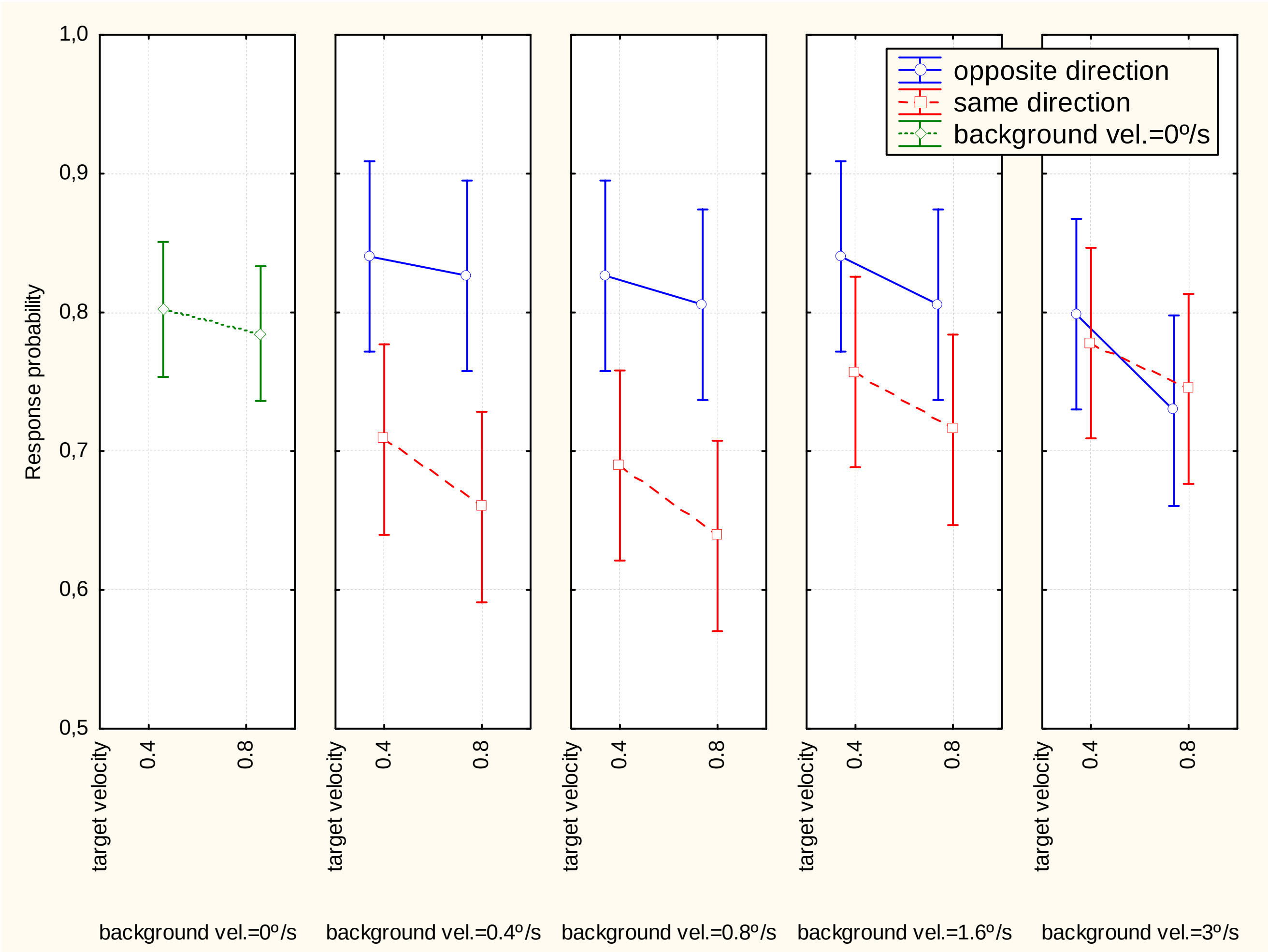

Figure 6. Response probability (1 as a correct response, 0 as an incorrect response) to target motion onset on different velocity conditions (°/s) and direction conditions. Note: the velocity values are absolute. Vertical bars denote 95% confidence limits.

It is clear that when background and target area are both moving under 1.0°/s and in the same direction, there are more incorrect answers about the direction of the target. In the conditions where background is moving 3.0°/s (the highest velocity used in the experiments) there is no difference in the direction of motion and the results resemble the result of the condition where background is stationary (with a certain number of accidental mistakes).

Comparing the response accuracy with the RT-s to target motion onset a bit of a dissociation can be seen - the control experiment shows that when the both areas are moving in the same direction and background velocity is under 1.0°/s more mistakes are made answering about the direction of target motion, i.e stronger effect of the background, while the RT-s do not show a discrepancy that strong. When the subjects had to discriminate between directions, the background moving in the opposite direction improved their probability of answering correctly, but the background moving in the same direction made it worse fot both target conditions (0.4º/s and 0.8º/s). But as a comparison in Figure 5 we see that RT results show this tendency only in case of the slowest target velocity 0.4º/s.

General discussion

The broad aim of the present study was to investigate how and on which conditions the motion of the background affects the percept of target motion, since according to the principles of global motion analysis and relative motion, information from different locations in the visual field is integrated in the process of perception. This was done by manipulating the different parameters of the background and target field.

Some general conclusions on present results can be drawn that match with the results of many previous studies in the field of psychophysics. The overall pattern of registering sensory information was confirmed- faster moving targets are more quickly detected than slower moving targets (Allik & Dzhafarov, 1984; Tynan & Sekuler, 1982; van den Berg & van de Grind, 1989). In addition, it was shown that with the increase of target velocity the effect of the surrounding area decreases (Ido, et al., 2000). Also a relatively well-established negative power function (as a computing mechanism) between the RT to motion onset and velocity of the motion was confirmed (Dzhafarov et al., 1993).

After the first series of experiments (the large target area with a diameter of 8.26º as a target stimulus) it seemed that motion detection on high target velocities is influenced by background motion in general, not so much by the distance between the two moving areas and is quite modest (confirmed by the results of insignificant background velocity effects when the target was moving over 1°/s). There was no significant gap effect which contradicts the adjacency principle (e.g. Holmgren, 1973), but we assumed that it was caused by the relatively large target area. The results of the series of experiments where the target area was reduced to a diameter of 1.2 º confirmed this assumption and are in agreement with previously reported data (e.g. Chang & Julesz, 1984; Nawrot & Sekuler, 1990; Murakami & Shimojo, 1993) that the size of the target stimulus plays an important role in the amount of the effect the background has on the target.

What was unexpected (especially after the results of the experiments with the large target area) was that on certain stimulus conditions (when the target area is small (with a diameter of 1.2°), not separated from the background and with the velocity under 1°/s) the moving background in the same as well as opposite direction prolonges the detection of target motion onset. This tendency (though a very modest one) was also reported in the previous work of the author (Kuldkepp, 2005). This is not congruent for example with the results found by Tynan and Sekuler (1975) that confirmed the basic principle of motion contrast: when center and surround were moving in opposite directions, the increase in surround velocity resulted in the increase of perceived velocity of the target. Most of the research on motion perception share an understanding that sensitivity to motion is based on contrast effect or assimilation- surround moving in the same direction with an object makes motion detection worse, surround moving in the opposite direction makes object motion detection better because of the contrast effect between the two moving areas. In the present study (under those previously specified conditions) there was no contrast effect and the approximation results confirmed it- moving background always slowed down the subjectively perceived target velocity. This interference among nearby moving elements is often explained by „compulsory averaging" of signals (e.g. Parkes, Lund, Angelucci, Solomon & Morgan, 2001), but can not be generalised to all the data. For example Bex and Dakin (2005) argue that their data on complex motion conditions can not be explained by the a simple compulsory averaging model and this is also true concerning the results of the present study. If it was the case of compulsory averaging of the velocities and directions, the apparent shift of perceived velocity (see Figure 4) should be positive in case of the background moving in the same direction and negative in case of the background moving in the opposite direction. All the ΔV values were negative (except for the condition of stationary background) and it shows that velocities are not added or subtracted. Moving background (in spite of the direction of it) always prolonged the detection of target motion onset and it seems like the target „lost" some of its speed (approximately 0.2-0.3°/s) despite its original velocity. So as it is well-established that the speed of detecting motion onset decreases with the decrease in velocity, it is obvious that it took more time for the subjects to react in the presence of the moving background. The fact that visual acuity can be reduced under crowded conditions (which the condition of different moving stimuli in the visual field with no doubt is) shows the limited capacity of the analysator and apparently problems with dividing resources. We would predict that instead of compulsory averaging there is a process of compulsory capacity dividing going on in our visual system: some of the information about target motion is lost when there are other moving stimuli in the visual field.

A question might rise if there were masking effects. It would make sense only for the stimulus conditions were target area and background started moving at the same time (to refresh the readers` memory- there were three SOA values used: 0 ms, 500 ms and 1000 ms), since masking is limited in time and 500 ms SOA already rules it out. Mean RT-s to target motion onset were in fact analysed by different SOA values, but no significant differences were found, so it was not masking that took place.

Tynan and Sekuler (1975) reported that when center and surround of their display were moving in the same direction, with the increase in the surround velocity the perceived velocity of the center first decreased and then increased. The perceived velocity reached its minimum at about the point where surround and center velocities were equal. They suggested an inhibitory interaction where the apparent speed reduction depends upon the center-surround speed differential. A similar inhibitory interaction was found in the control experiment of the present study. The response accuracy (for detecting the direction of target motion) was lower when the background moved under 1°/s (so both, target and background values were either 0.4°/s or 0.8°/s). This was not confirmed by mean RT-s, but this could be so because of the much lower stimulus velocities used. Most of the target velocities in the present study were under 1°/s and the highest was 1.6°/s, while the target velocity Tynan and Sekuler used was 2.8°/s and their background velocities ranged from 1.4°/s up to 5.6°/s. In the previous work of the author (Kuldkepp, 2005) this similarity principle also ocurred that resembled the results of Tynan & Sekuler (1975) and in both of those studies higher stimulus velocities were used.

One of the drawbacks of the current work should be mentioned. Tynan & Sekuler (1975) have showed that stationary dots in the center area of a random-dot display appear to move in the opposite direction of the moving dots in the surrounding area, a case of induced motion. In the current set of experiments no stationary target was used, mainly because when measuring the detection of motion onset by RT method it could be confusing for the subjects to have an instruction to react to moving target and then have no moving target on the display. Yet it should be admitted that the question of induced motion or assimilation in case of stationary target area remains unanswered in the present study.

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References

Allik, J., & Dzhafarov, E. N. (1984). Reaction time to motion onset: local dispersion model analysis. *Vision Research, 24,* 99-101.

Becklen, R., & Wallach, H. (1985). How does speed change affect induced motion? *Perception & Psychophysics, 37,* 231-236.

Bex, P.J., Dakin, S. C., & Simmers, A. J. (2003). The shape and size of crowding for moving targets. *Vision Research, 43,* 2895-2904.

Bex, P. J., & Dakin, S. C. (2005). Spatial interference among moving targets. *Vision Research, 45,* 1385-1398.

Chang, J. J., & Julesz, B. (1984). Cooperative phenomena in apparent movement perception of random-dot cinematograms. *Vision Research, 24,* 1781-1788.

Chung, S. T. L., Levi, D. M., & Legge, G. E. (2001). Spatial-frequency and contrast properties of crowding. *Vision Research, 41*, 1833-1850.

Cropper, S. J. (2001). Local and global motion signals and their interaction in space and time. In Zanker, J. M., & Zeil, J. (Ed.), *Motion Vision- Computational, Neural and Ecological Constraints* (pp. 125-140). Springer Verlag.

Dzhafarov, E. N., Sekuler, R., & Allik, J. (1993). Detection of changes in speed and direction of motion: Reaction time analysis. *Perception & Psychophysics, 54,* 733-750.

Gogel, W. C., & Tietz, J. D. (1976). Adjacency and attention as determiners of perceived motion. *Vision Research, 16,* 839-845.

Gogel, W. C., & McNulty, P. (1983). Perceived velocity as a function of reference mark density. *Scandinavian Journal of Psychology, 24,* 257-265.

Holmgren, S. (1973). A „Mach band type" phenomenon in the visual perception of motion. Report 142, Dept. of Psychol., Univ. of Uppsala, Sweden.

Ido,K., Ohtani, Y., & Ejima, Y. (2000). Summation between nearby motion signals and facilitative/inhibitory interactions between distant motion signals. *Vision Research, 40,* 503-516.

Kreegipuu, K. (2004). Availability and accessibility of information in perception of moving stimuli. *PhD Dissertation.* Tartu: Tartu University Press.

Kuldkepp, N. (2005). Liikumise alguse avastamine sõltuvalt tausta liikumisest. (Unpublished bachelor`s thesis).

Kyllingsbæk, S., Valla, C., Vanrie, J., & Bundesen, C. (2007). Effects of spatial separation between stimuli in whole report from brief visual displays. *Perception & Psyhophysics, 69,* 1040-1050.

Murakami, I. (1998). Motion-transparent inducers have different effects on induced motion and motion capture. *Vision Research, 39,* 1671-1681.

Murakami, I., & Shimojo, S. (1993). Motion capture changes to induced motion at higher luminance contrasts, smaller eccentrities, and larger inducer sizes. *VisionResearch, 33,* 2091-2107.

Murakami, I., & Shimojo, S. (1996). Assimilation-type and contrast-type bias of motion induced by the surround in a random-dot display: Evidence for center-surround antagonism. *Vision Research, 36,* 3629-3639.

Nakayama, K., & Tyler, C. W. (1978). Relative motion induced between stationary lines. *Vision Research, 18,* 1663-1668.

Nawrot, M., & Sekuler, R. (1990). Assimilation and contrast in motion perception: explorations in cooperativity. *Vision Research, 30,* 1439-1451.

Paffen, C. L. E., te Pas, S. F., Kanai, R., van der Smagt, M. J., & Verstraten, F. A. J. (2004). Center-surround interactions in visual motion proessing during binocular rivalry. *Vision Research, 44*, 1635-1639.

Parkes, L., Lund, J., Angelucci, A., Solomon, J. A., & Morgan, M. (2001). Compulsory averaging of crowded orientation signals in human vision. *Nature Neuroscience, 4,* 739-744.

Treue, S., Hol, K., & Rauber H.-J. (2000). Seeing multiple directions of motion-physiology and psychophysics. *Nature Neuroscience, 3,* 270-276.

Tynan, P., & Sekuler, R. (1975). Simultaneous motion contrast: velocity, sensitivity and depth response. *Vision Research, 15,* 1231-1238.

Tynan, P., & Sekuler, R. (1982). Motion processing in peripheral vision: reaction time and perceived velocity. *Vision Research, 22,* 61-68.

van den Berg, R., Roerdink, J. B. T. M., & Cornelissen, F. W. (2007). On the generality of crowding: Visual crowding in size, saturation, and hue compared to orientation. *Journal of Vision, 7,* 1-11.

van den Berg, A. V., & van de Grind, W. A. (1989). Reaction times to motion onset and motion detection tresholds reflect the properties of bilocal motion detectors. *Vision Research, 29,* 1261-1266.

Wallach, H., O`Leary, A., & McMahon, M. L. (1982). Three stimuli for visual perception compared. *Perception & Psychophysics, 32,* 1-6.