EPILOGUE
Where?

The aim of the present thesis was to contribute to the better understanding of the cause of perisaccadic compression. In order to do so, we attempted to dissociate between some generally co-varying aspects related to the phenomenon of perisaccadic mislocalization, so as to clarify their roles.

The first question in this thesis (Chapter 2) was whether compression is towards the saccade target position, or towards where we are looking at the end of the saccade. To dissociate between the two, we made use of a visual illusion that influences the perceived distance to the target of the saccade and thus the saccade endpoint (Yarbus, 1967; Festinger et al., 1968; Binsted and Elliott, 1999; Bernardis et al., 2005; de Grave et al., 2006; de Grave and Bruno, 2010; Figure 1.2) without affecting the perceived position of the saccade target (the endpoint of the shaft; Gillam and Chambers, 1985; Mack et al., 1985; Smeets et al., 2002). Our results showed that the Müller-Lyer illusion affected the amplitude of the saccade. It also affected the pattern of mislocalization during saccades, with flashes presented on the fins-out configuration of the figure (--><) being perceived as being further from the initial fixation position than flashes presented on the fins-in configuration of the figure (<-->). This is clear evidence that mislocalization during saccades is related to the eye orientation at the end of the saccade and not to the position of the saccade target within the image, because only the former differed between the two configurations of the figure. Further analysis revealed that the magnitude of the effect of the illusion on localization was very close to what one would expect for compression toward the position that is fixated at the end of the saccade, considering the amount of compression and the influence of the illusion on the saccade amplitude.
The second question of the present thesis (Chapter 3) was whether compression is a special characteristic of the retinal resolution being so much higher where one is looking than elsewhere, or whether it is related to the position at which one directs one’s gaze at the end of the saccade, no matter the retinal resolution. Normally, fixating a position means that its image falls on the fovea. Macular Degeneration (MD) damages the central retina, obliterating foveal vision. Many people with MD adopt a new retinal locus for fixation, called the preferred retinal locus (PRL). The location of the PRL need not even be the location of highest acuity on the retina (Shima et al., 2010). MD provides a unique opportunity to distinguish between various origins of perisaccadic compression, because although the PRL in people with MD is similar to the fovea of people with normal vision in terms of defining where one is looking, it is quite different in terms of variations in retinal resolution. In particular, the decline in resolution is very different for different directions from the PRL, with a very extreme change towards the macula, and quite modest changes in the other directions. We found that a person with MD, who has a loss of foveal vision, showed a clear compression towards her PRL. We concluded that perisaccadic compression is not a special characteristic of the retinal resolution being so much higher where one is looking, but is related to the position that is fixated after the saccade, no matter its retinal resolution.

In Chapter 4, we attempted to dissociate the roles of gaze and eye displacement on perisaccadic mislocalization. The observed compression of perceived positions has been found to increase with the amplitude of the saccade (Lavergne et al., 2010). In most studies on perisaccadic compression the head is static, so the amplitude of the saccade is equal to the gaze change that is achieved by rotating the eyes in the head (eye-in-head).
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For that reason, it was unclear whether it was the parameters of the gaze shift that were positively correlated with the magnitude of compression or the parameters of the eye-in-head rotation. To distinguish between the two, we asked participants to shift their gaze between two positions, either without moving their head or with the head contributing to the change in gaze, and to localize a flash presented around the time of the saccade (Figure 1.4). When the head was static, the change in gaze was mainly generated by a rotation of the eyes in the head. When the head was moving, the change in gaze was partially generated by a rotation of the eyes in the head and partially by a rotation of the head, resulting in a decreased eye-in-head rotation for a given shift in gaze. Our results showed less compression when the head contributed to the change in gaze, and a positive correlation between the magnitude of compression and the parameters of the rotation of the eyes relative to the head.

Finally, in Chapter 5 we questioned whether spatial localization of a flash presented around the time of a saccade involves judging the time of the flash. We hypothesized that if errors in judging the time of the flash are (partly) responsible for the reported spatial mislocalization of flashes presented around the time of saccades, we should be able to manipulate the pattern of mislocalization by altering the perceived time of the flash. To dissociate between misjudging space and misjudging time, we presented a relevant flash (red bar; Figure 1.5) within a short rapid sequence of irrelevant flashes (black bars; Figure 1.5) and asked participants to localize it. The relevant flash was always at the same spatial location but in different temporal order (second or fourth) in the sequence of five bars. We found that when the relevant flash was presented second in the sequence, it was judged to be further in the direction of the saccade than when it was
presented fourth in the sequence. This is evidence that the spatial localization of flashed stimuli involves judging the eye orientation at the estimated time of the flash.

Altogether the results of the present thesis support the temporal uncertainty explanation (Maij et al., 2011a) rather than the remapping explanation (Ross et al., 2001) for perisaccadic compression.

That compression is towards the endpoint of the saccade rather than the saccade target position (Chapter 2) is in line with Maij et al. (2011a) who successfully modeled perisaccadic mislocalization as a combination of uncertainty about the time of the flash and a bias to localize targets where one is looking.

That compression is not a special characteristic of the retinal resolution being so much higher where one is looking than elsewhere, but is related to where one is looking, no matter the retinal resolution (Chapter 3), is inconsistent with remapping explanations that relate compression to variations in spatial resolution across the visual field (Ross et al 1997; VanRullen 2004; Hamker et al 2008). That compression is also observed before and after the saccade in an MD participant (MH; and not in the controls) is also consistent with MH’s larger uncertainty about the position before and after the saccade than that of the controls.

In addition, according to the temporal uncertainty explanation, faster saccades lead to stronger compression because the same temporal uncertainty corresponds with a larger spatial uncertainty for a faster change in gaze. Our finding that eye-in-head velocity rather than gaze-velocity is critical with respect to the resulting compression (Chapter 4) is in line with this explanation for the compression component of
perisaccadic mislocalization, if one assumes that compression depends on the resolutions of the separate judgments of head and eye orientation.

Finally, our finding that the spatial localization of flashed stimuli involves judging the eye orientation at the estimated time of the flash (Chapter 5) is in line with the temporal uncertainty explanation, which suggests that the item of interest (the flash) first has to be detected and the relevant eye orientation is subsequently estimated in order to localize it. In contrast, the remapping explanation predicts that the temporary remapping of positions in space during the eye movement should affect all elements in a scene (Ross et al 1997), before the stimulus of interest has been selected, leaving ordinal relationships between positions intact.

The results altogether show that the critical aspects in each of these studies are the aspects that one would expect to be critical if perisaccadic mislocalization is caused by temporal uncertainty (influence of sequence of flashes and determined mainly by the faster eye movements, not gaze) and a bias towards where one is looking (endpoint of the saccade, not saccade target or fovea).

I hope that this thesis will contribute to the better understanding of the origins of perisaccadic compression. Is the compression an artifact of the limited temporal resolution of both vision and information about eye orientation, or is it part of an ingenious method for perceiving a stable world despite moving one’s eyes? Of course the latter sounds more exciting, so I do not expect to immediately convince everyone that the former is true. However, I would like to convince the readers to carefully consider the evidence for the two viewpoints and decide for themselves. Generally accepted viewpoints certainly contribute to a better understanding of our behavior and nature.
They define a context within which more questions arise, and therefore research improves. Nevertheless, it is useful to consider whether we need to restrict our interpretations within this viewpoint. It is equally important to also consider evidence in favor of opposing views. In the present thesis I have presented evidence that can explain the phenomenon of perisaccadic compression within a less common viewpoint. I hope that the studies in this thesis will encourage readers to consider the possibility that perisaccadic compression is primarily the result of temporal uncertainty.