Summary

Visual perception is thought to rely largely on attention which selects salient or relevant information for further processing, and filters out competing content. This thesis investigates the time course of attentional selection, as based on two signal types: external cues and internal representations. While external cues, such as a flash of light, draw attention to their specific locations in an automatic manner, internal representations are maintained by the observer and they direct focus to matching features or objects. Importantly, attentional selection is a dynamic process, as its effects on perception change over time. Therefore, in order to understand the effects of attention, it is also necessary to understand its time course.

Previous studies have proposed that attentional selection as based on spatially specific external cues is characterized by rapidly, but only temporarily improved target discrimination at the location of the cue. This has been thought to reflect a transient attention component. Chapters 2-4 used a cueing task to investigate what specifically makes attention transient. In this task a cue indicates the location of the target, and the time between the two can be varied to look at how target discrimination is affected by cueing over time.

In Chapter 2 we investigated which attentional processes may explain the transient attention performance pattern. An external cue may evoke at least three different processes: general alerting (non-specific improvement of performance because the observer becomes alerted by the cue), spatial shifting (to the cue location when the observer has to initially attend to a central point), and selectivity (when the target is presented with a number of irrelevant distractors). We controlled for general alerting and spatial shifting, and manipulated selectivity by presenting the target either alone or with irrelevant distractor objects. The results consistently showed that spatially specific cues improved target discrimination accuracy with a time course that was dependent on the presence of competition, and thus selectivity. Performance rose rapidly, up to about 100 ms irrespective of condition, consistent with the earlier estimates of the fast build-up of attention. However, at later times accuracy declined again, but only if the target was surrounded by distractors. When the target was presented alone, performance was sustained or even improved further with time. These results thus strongly suggest that external signals lead to a rapid, but transient selection of subsequent target information, and that this transience is caused by the presence of competing visual information. Selectivity then best explains the transient component of attention.
A following question is whether certain type of competition is needed for the attentional response to become transient. In Chapter 3 we generalized the results of Chapter 2 to different tasks and competition types. The findings of Chapter 2 were replicated in conditions in which the target location was variable rather than fixed. Furthermore, we found that competition by similarity, incompatibility, and proximity between the target and distractors impaired performance, but did this independent of the temporal cueing effects. Importantly, the transient pattern was found for all conditions that included competition. It thus seems that the mere presence of competition is sufficient to reveal transient attention that is evoked by cueing, and that the level of processing at which this competition occurs does not matter.

Our results have so far shown that in optimal conditions, when an external cue signals a target that is the only item on the screen, performance should be rapidly improved and then remain sustained. However, other studies have revealed a rather different picture, i.e. that performance becomes worse some few hundred milliseconds after the cue. These studies used cueing tasks with letters as stimuli, whereas we have used meaningless line segments. In Chapter 4 we examined whether the properties of the cue and the target would also modify the time course of attention. The simple line targets resulted in the typical rapidly enhancing and sustained pattern of performance, and this effect was rather independent of cue type. However, performance for letter targets was prone to the effects of cue salience and shape. Specifically, for the first 75 ms, target discrimination accuracy was found to be enhanced if the cue was weak, whereas no such benefits were found after salient cues. In addition, if the cue and target letter were dissimilar in shape, performance was suppressed at later cueing intervals, similar as was found in previous studies. The error pattern further suggested that the suppression was at least partially caused by confusing the target and cue representations with each other. In sum, Chapter 4 thus shows that the time course of attentional selection can be changed by both lower and higher level properties of the cue and the target. This applies especially if letters are used as stimuli, whereas the time course of simpler stimulus types appears relatively robust.

While Chapters 2-4 studied attentional selection by external, spatially specific signals, Chapters 5 and 6 focus on the time course of attentional selection that is based on an internal representation of the target feature. In this scenario people know what to look for, but not where to look, as the target feature instead of location is indicated. Such selection has been studied earlier using visual search tasks in which the target identity or feature was indicated by a cue, presented at the center of the screen. However, the
picture that has emerged from these studies has been mixed, probably due to methodological problems, as the current thesis shows.

In Chapter 5 we investigated the time course of attentional selection as based on a memory of target feature. Earlier studies have examined this by using cues that directly show the target. However, this has the problem that the cue may be not only encoded into working memory but also cause priming that is thought to be a more automatic type of memory. In addition, previous studies have often measured reaction times, but these have turned out to be inconsistent in indexing the temporal effects of attention. Chapter 5 used a different type of cueing manipulation in order to circumvent priming. Specifically, in our task observers first memorized two possible target colors, after which a neutral postcue pointed to one of these colors that was then used for searching a target. Instead of a direct visual cue, we thus measured performance as a function of the postcue. In two experiments, either RTs or performance accuracy were measured. When RTs were used, no changes in selectivity for the cued target color were found over time. In contrast, the accuracy task revealed that cueing the memory template enhanced selectivity gradually up to 400 ms, after which it then slightly declined. Based on these results we argue that accuracy provides a better estimate of temporal cueing effects on selectivity than RT. Moreover, Chapter 5 suggests that attentional selection as based on memory representation, and not on priming, has a time course that rises up to about 400 ms and is then sustained or declines again.

In Chapter 6 we further investigated whether the type of representation plays a role in signaling attentional selection. Does the direct visual cue result in faster or otherwise more efficient selection than the postcued memory template? Furthermore, does the time course of selection differ when the memory representation is based on visual or verbal information? Previous studies have found that visual cues are always more effective than verbal cues, but this may have been due to priming. First, by using either a neutral (black) or visual (e.g. red, if the target was red) postcue, we found that selectivity was enhanced similarly irrespective of whether the search was based on seeing the target feature or activating it in memory. However, overall accuracies were affected by the cue type which suggested that visual cues caused priming, but only at the level of overall performance. Second, search performance was compared between memories that were formed from visual (colored patches) and verbal (words describing the colors) precues, while controlling for priming by using the neutral postcue. We found no differences between templates derived from verbal and templates derived from visual information, contrary to what has been suggested before. Furthermore, the results provide converging
evidence for the time course of selection as based on memory templates: enhancement up to 400 ms after which selectivity levels off or declines.

To conclude, the chapters of this thesis shed new light on how attentional selection develops over time. Attention triggered by external signals builds up rapidly within the first 100-200 ms, after which it declines again, provided that there is competition by irrelevant stimuli. This transience can be caused by various types of competition, occurring at different levels of processing. Therefore, the selectivity component of attention that is needed to bias processing towards the cued item best explains the transience of externally signaled attention. Selection as based on an internal target template develops more slowly, requiring about 400 ms to reach an optimal level. After this peak, performance also appears to decline again. This type of selection can be initiated both by memory template of target feature, and visual cue directly showing that feature. Such memory template is suggested to be equally effective when it is formed from either visual or verbal information, in contrast with previous claims.