Summary

Finding your wallet in your bag, detecting the light switch in a dark room, these are both examples of haptic search tasks. In such a task, a specific target object must be detected among other objects that are not of interest. Some searches are much easier than others, and this depends on the specific properties of the target and distractors. When a property is efficiently perceived among others, this property is salient with respect to its context. In Chapters 2 and 3, I investigated whether movability and compliance could be salient haptic features.

To see whether movability was salient, the search for a movable ball or an anchored ball in ball transfer units was examined (Chapter 2). The ball transfer units were placed on a display and participants had to slide their hand over the display and detect the presence of a movable ball among anchored ones or vice versa. The search for a movable ball among anchored distractors was much easier than the other way round. In this case, the reaction time (i.e., the time to detect the presence of a target) did not change with the number of items. In other words, the slope of the reaction time against the number of items, the search slope, was flat. In addition, it was demonstrated that the movements made in the search for a movable target were faster and shorter than those in the search for an anchored target and mainly in the horizontal direction. This suggests that a parallel strategy can be used in the search for a movable target. The items in the set can be explored together and the target pops out of the display. To further investigate what sensation might underlie the pop-out of movability, the vibration and friction of the stimulus displays were measured. This indicated that the vibratory signals caused by the mechanical interactions between the ball and its casing might explain the effect.

Other properties that were examined for their saliency were hardness and softness (Chapter 3). Two different modes of exploration were used in the search. In the first method, hard and soft spheres were held in the hand so they could be freely manipulated. It was found that both a hard target among soft distractors and a soft target among hard distractors popped out. However, the difference between the target and distractors must be sufficiently large, because with a small difference the search was serial for both conditions. In the second method, the spheres were placed on a display and had to be pressed with the hand. Here, a search asymmetry was found. The hard sphere was still detected easily, but the soft sphere was more difficult to find. It seemed that the position

of the target and distractors influenced the search for the soft sphere. When the soft target was surrounded by hard distractors, the hand was blocked so the soft sphere was difficult to perceive.

Together, Chapters 2 and 3 indicate that movability, hardness and softness can be considered haptic salient features. The perception of these properties is efficient and fast. They might be important in the recognition of objects in the early phases of perception.

Because a salient feature is detected very easily, it can enhance search performance. However, it is possible that it might also disrupt the search, even when it is irrelevant for the search. This question was addressed in Chapter 4 for the properties roughness and edges. In accordance with the literature, it was found that the search for a rough target among smooth distractors was easier than the reversed situation. Similarly, the search for a cube (with edges) among spheres was easier than the search for a sphere among cubes. Furthermore, this study demonstrated that roughness and edges could also disrupt a search task. When comparing the roughness search when stimuli were all spheres to the situation when all items were cubes, the latter condition was much slower. The same result was found in the search for a cube among spheres: the search in rough items was more difficult than the search in smooth items. So, even when a salient feature is irrelevant and present in all the stimuli, it can still influence the search performance. This disruptive effect was only found when the previous search was easy. When searching for a smooth target among rough distractors, there was no difference regardless whether all items were spheres or cubes. Neither was the search for a sphere among cubes influenced by roughness. This can be explained because these searches were already difficult and performed in a serial way, so there will not be much decrement in performance.

The studies described above all investigated situations in which the target differed in a single property from the distractors. When the difference between the target and distractors was larger, search performance improved (Chapter 3). Possibly, the search can also be performed faster if the target differs in two properties from the distractors. If the search is faster compared to both conditions with a single available cue, this means the properties are integrated. In Chapter 4 was shown that shape and texture could be integrated in haptic search. This effect was found when the combined features were both not salient (smooth and spherical). The properties seemed to be independently processed in a parallel way. Moreover, the integration effect appeared to be more effective if the properties were located in a single target than in two separate targets (Chapter 5).

The balance between disruptive and beneficial effects of salient features was different for roughness and shape properties. The search conditions and the model that was made in Chapter 4 suggested that, at least for these property values, shape was a more beneficial cue whereas roughness seemed to be more disruptive.

Lastly, the saliency of a target has a large effect on how the search is performed. That is, different exploration movements are used depending on how easy the target is to find. Search slopes indicate whether a more parallel (all items searched at once) or serial (items searched one by one) strategy is used. However, in haptic search, the investigation of the exploration movements can aid the interpretation of the slopes. In Chapters 6 and 8, movements were classified into different categories by a set of criterion variables. More fluent, simple movement strategies were used when the target was salient. This was demonstrated in a task where the stimuli were presented on a display (2D set-up, Chapter 6) and also when stimuli were held in the hand (3D set-up, Chapter 8). Parallel movement strategies were used in the search for a salient property, whereas detailed, serial explorations were seen if the target was difficult to find. It seems that the exploration movements were adjusted more to the saliency of the target, than to the specific target property that was searched for.

Furthermore, a tool to investigate exploration movements in haptic perception was presented in Chapter 7. This consists of a model of the hand that can be determined from a small number of sensors that are tracked during exploration. With this model, I could examine which parts of the hand contacted the target object in the search. In this way, I could investigate which parts of the hand contributed to the search (Chapter 8). Results showed that the fingertips, particularly the thumb, were used more extensively to detect a target in difficult searches compared to easy searches. This was in agreement with the strategies that were performed in these tasks, where the thumb was used to explore or move the stimuli in the hand. In conclusion, the saliency of object properties has an influence on how we perceive objects and how we perform a perceptual action.