Cold Objects Pop Out!

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Abstract. We can haptically extract thermal properties of different material, but we can also sense object temperature. It has been shown that thermal properties of materials are not very salient features. In this study, we investigate saliency of actual temperature differences. To this end we let subjects grasp varying numbers of spheres in the hand. These spheres were warmer (38°C) than the hand temperature, but in half of the trials there was one sphere colder (22°C) than the hand temperature. Subjects had to indicate whether the cold sphere was present and response times were measured as a function of the number of spheres. This yielded a target present slope as small as 32 ms/item. This is comparable to slopes found earlier for search for a tetrahedron among spheres and indicates that there is pop-out effect for a cold sphere among warm spheres.

Keywords: Haptic search, Temperature perception, Psychophysics.

1 Introduction

Haptic object recognition relies on cues like shape, size and material properties. Some properties like the presence of edges or rough materials [1,2,3] have been shown to be very salient properties that make an object stand out among others. Also thermal properties can play a role in object identification. It has been shown that for large differences in thermal properties, materials can be reliably discriminated using these properties [4].

Saliency of object properties can be investigated using haptic search tasks. These tasks have been adapted from visual search tasks, in which subjects generally have to search for a certain 'target' item (e.g. a green dot) among varying numbers of 'distractor' items (e.g. red dots). Response times are then measured as a function of the number of items and the slope of this function is interpreted as a measure of the efficiency at which the search task was performed. Small slopes mean that the number of distractor items did not increase response times much and indicate that the search was performed 'in parallel' over all presented items [5,6]. In this case, the target differs from the distractors in terms of a salient feature and this feature is said to 'pop out'.

Lederman and Klatzky performed a haptic search task in which subjects had to search for a target material (copper) that felt cooler than the distractor material (wood) [1]. In that study all materials were at room temperature, meaning that both materials felt cold. Saliency of actual temperature differences may be quite different. In the present study,

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we set out to investigate saliency of a cold object among warm objects. In this case, the material of the target and distractor items was the same, but the target item had a temperature below skin temperature, while the distractor items were warmer than the skin. Knowledge about saliency of temperature differences could be useful for design of haptic interfaces in which temperature is used to present abstract information such as proximity or direction (see [7] for an overview of such applications).

2 Experimental Design and Setup

2.1 Participants

Ten paid subjects participated in the experiment (mean age 24 ± 3 years). Two of them were left handed, while all others were right handed according to Coren's test [8]. None of them reported any known hand deficits.

2.2 Stimuli and Setup

The items consisted of brass spheres (radius 0.93 cm) which were suspended from flexible wires. The thermal conductivity of brass is 119 W/mK, the specific heat is 380 J/kgK and the density is 8800 kg/m^3 . This means that the spheres exchange heat with the surroundings relatively fast. Sets of 3, 4, 5 or 6 spheres were presented and in half of the trials a target item was present. The target item was a sphere with a temperature of 22°C, while the other spheres (distractor items) had a temperature of 38°C. The items as well as the hand of the subject were temperature controlled by placing them in water baths with a piece of plastic on the water surface to prevent contact with the water underneath. Room temperature was 21 ± 1°C (SD). The water bath for the target items as well as that for the hand of the subject were temperature controlled using aquarium heaters (Tetratec 25 and Tetratec 200). The water bath for the distractor items was controlled by adding hot water during the experiment and was maintained at a temperature of 41 ± 2°C (SD). Because the distractors had to be much warmer than room temperature it was necessary for the water bath to be about 41°C in order to heat the distractor items to 38 ± 1°C (SD). Temperature of the spheres was measured prior to the experiments using a temperature sensor (Dallas semiconductor DS600) placed on the surface of a sphere, recording at 1 Hz. During the experiments only the temperature of the water baths was monitored. Figure 1a shows the temperature over time of an item at room temperature that was placed on the water bath. It can be seen that it heated to 38°C in approximately 9 min. The spheres were placed in the water bath at least 30 minutes prior to the start of the experiment. Figure 1b shows the temperature of a distractor sphere that was removed from the water bath and placed back again. The temperature decrease and increase were approximated using a linear model and slope values are indicated. In half a second the temperature of the distractors decreased by (0.0035°C/s $\times$ 30s =) 1°C. The spheres were taken out of the water bath only a few seconds before a trial was started and were placed back immediately after the trial. Therefore, it is reasonable to assume that the initial temperature of the distractors was always in between 37°C and 39°C. Five sets of target and distractor spheres were used

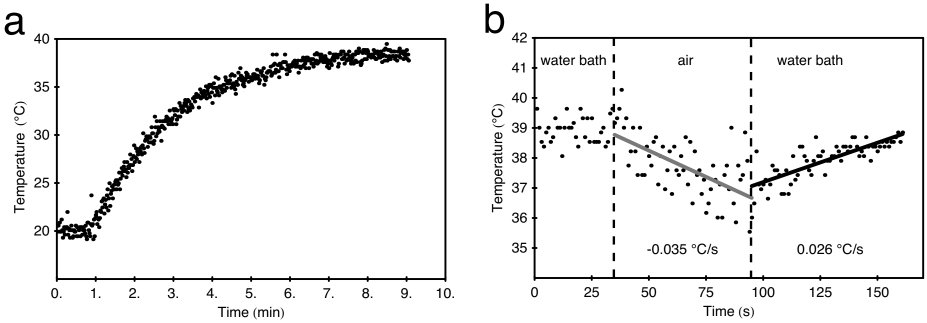

Fig. 1. Temperature recorded in time a) for a sphere at room temperature placed in a water bath of 42°C and b) a sphere in a water bath of 42°C removed to be suspended in air and placed back again in the water bath. The solid lines represent linear regression and the slope values are indicated in the figure.

subsequently so that there was time for the items to regain their temperature after each trial.

Upon arrival subjects were asked to place their dominant hand on the plastic covering a water bath of 30°C for 5 minutes. After every ten trials the subject was asked to place his or her hand back onto the water bath for 1 minute. Hand temperature was measured before the experiment was started and after the experiment. Hand temperatures ranged from 28°C to 33°C. This means that for all subjects the target sphere was below skin temperature and the distractor spheres were above skin temperature.

Response times were measured using a custom built device (see [9] for details about this set-up). Time measurement was started automatically when the subject touched the stimuli and was terminated with a vocal response.

2.3 Experimental Design

Subjects placed their hand palm upwards below the spheres. They were instructed to grasp the spheres and respond as fast as possible whether the target item was present (Figure 2). After each trial, feedback was provided on whether the answer was correct. There were no restrictions on hand movements other than having to initially grasp all items simultaneously. After grasping all items, they were allowed to release items from the hand and the experimenter scored whether items were released during the the trial. All numbers of spheres were presented 20 times, 10 times target present and 10 times target absent. Error trials were not included in the analysis and repeated at the end of the experiment to ensure an equal number of trials for each numerosity. Prior to the experiment, at least 20 practice trials were performed in order to let to subject become acquainted with the task. Practice trials were continued until 10 trials in a row were performed correctly, but it was never necessary to exceed 20 practice trials for any of the subjects. The experiment was run in a single one hour block of trials per subject.

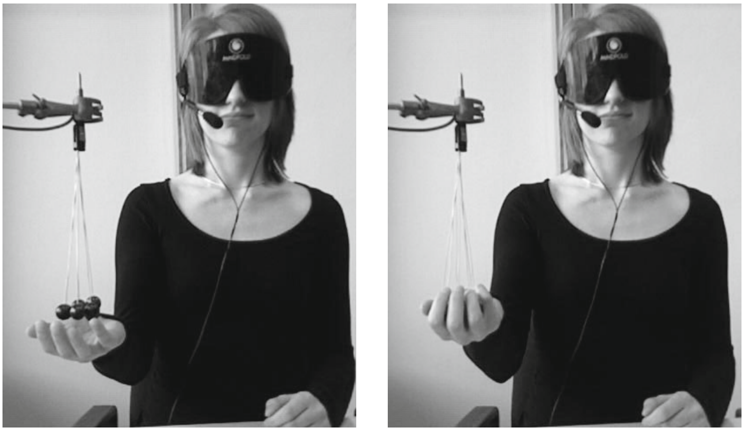

Fig. 2. A blindfolded subject grasping a set of spheres suspended above the hand

3 Results

Error rates were overall low (2.3 %) and the highest error rate of 5 % was reached for five items in the target present case. Subjects never released spheres from the hand. Generally they only grasped them in the hand and did not move them around much.

The response times as a function of the number of items averaged over all subjects are shown for the target present trials in Figure 3a and for the target absent trials in Figure 3b. The solid lines represent linear regression weighted according to the inverse squared standard error. This yielded a target present slope of 32 ± 7 ms/item and a target absent slope of 72 ± 1 ms/item. In this case the reported uncertainty in the slope values is the standard error that resulted directly from the regression procedure. Linear regression was also performed on the single subject data. Averaged over subjects this resulted in a target present slope of 22 ± 46 ms/item and target absent slope of 79 ± 73

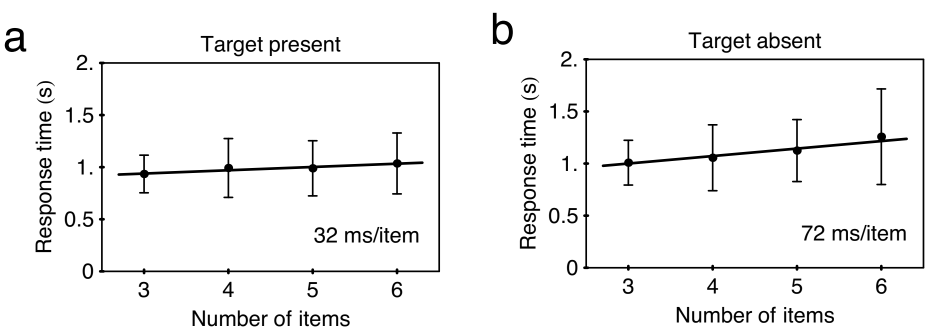

Fig. 3. Response times as a function of the number of items averaged over all subjects for the a) target present trials and b) target absent trials. Error bars indicate the standard deviation of the single subject means. The solid lines represent linear regression to the response times. Slope values are indicated in the figure.

ms/item. None of the single subject's target present slopes were significantly different from zero and for only three subjects the target absent slope was significantly different from zero at the 0.05 significance level.

A 2×2 (target presence $\times$ measure) repeated measures ANCOVA (Analysis Of Co-Variance) was performed on the slopes and the axis-intersections, with skin temperature (averaged over begin and end temperature) as co-variate. This analysis did not show any effects ($F(1,8) \leq 2, p \geq 0.2$).

4 Discussion and Conclusions

In a previous study we have shown that there is a whole range of possible response time slopes when searching for a certain target-distractor combination differing in shape [3]. In that study it was found that search for a tetrahedron among spheres(25 ms/item) was performed in parallel, while search for a tetrahedron among cubes (703 ms/item) was performed serially. In both cases the target present slope is indicated. The slope value (32 ms/item) from the present study indicates parallel search. Also the item release rate of 0% suggests parallel search, because in serial search generally items are released from the hand [3]. Therefore, the results clearly indicate that there is a pop-out effect for a cold object among warm objects.

The present results show that a cold object among warm objects is roughly equally salient as an object with edges among objects without edges. Lederman and Klatzky found that a copper target among wooden distractors is much less salient than the presence of an edge [1]. This shows that temperature differences are more salient than thermal properties of materials.

An explanation for this difference between saliency of thermal properties and saliency of temperature differences is the fact that two objects at room temperature differing in thermal properties normally both cause heat flow out of the skin, but at different rates. Therefore, both objects activate the same population of receptors and nerve endings in that case. On the other hand, a warm object causes heat flow into the skin, while a cold object causes heat flow out of the skin. In this case the cold objects are detected by a system of nerve fibres and receptors dedicated to cold perception, while the warm objects activate nerve fibres and receptors dedicated to warmth perception. Consequently, there is a categorical difference between an object below skin temperature and an object above skin temperature. Whether such a categorical difference is necessary for pop-out effect remains to be investigated.

Summarising, our results show that a cold object pops out among warm objects. Furthermore, slight variations in hand temperature among subjects did not affect the search slopes, which is practical for applications. The high saliency of a cold item among warm items make temperature differences useful as encoding variables in haptic interfaces.

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References

1. Lederman, S.J., Klatzky, R.L.: Relative availability of surface and object properties during early haptic processing. Journal of Experimental Psychology: Human Perception and Performance 23, 1680–1707 (1997)
2. Plaisier, M.A., Bergmann Tiest, W.M., Kappers, A.M.L.: Haptic pop-out in a hand sweep. Acta Psychologica 128, 368–377 (2008)
3. Plaisier, M.A., Bergmann Tiest, W.M., Kappers, A.M.L.: Salient features in three-dimensional haptic shape perception. Attention, Perception & Psychophysics 71(2), 421–430 (2009)
4. Ho, H.N., Jones, L.A.: Contribution of thermal cues to material discrimination and localization. Perception & Psychophysics 68, 118–128 (2006)
5. Treisman, A., Gelade, G.: A feature-integration theory of attention. Cognitive Psychology 12, 97–136 (1980)
6. Wolfe, J.M., Cave, K.R., Franzel, S.L.: Guided search: an alternative to the feature integration model for visual search. Journal of Experimental Psychology: Human Perception and Performance 15, 419–433 (1989)
7. Jones, L.A., Ho, H.N.: Warm or cool, large or small? The challenge of thermal displays. IEEE Transactions on Haptics 1, 53–70 (2008)
8. Coren, S.: The left-hander syndrome: The causes and consequences of left-handedness. Vintage Books, New York (1993)
9. Plaisier, M.A., Bergmann Tiest, W.M., Kappers, A.M.L.: Haptic search for spheres and cubes. In: Ferre, M. (ed.) EuroHaptics 2008. LNCS, vol. 5024, pp. 275–282. Springer, Heidelberg (2008)