Available online at www.sciencedirect.com
ScienceDirect
Acta Psychologica 127 (2008) 51–56
acta psychologica
www.elsevier.com/locate/actpsy

Haptic search is more efficient when the stimulus can be interpreted as consisting of fewer items

K.E. Overvliet *, K.M. Mayer, J.B.J. Smeets, E. Brenner

Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, 1081 BT Amsterdam, The Netherlands

Received 22 September 2006; received in revised form 11 January 2007; accepted 15 January 2007
Available online 28 February 2007

Abstract

In a typical haptic search task, separate items are presented to individual fingertips. The time to find a specific item generally increases with the number of items, but is it the number of items or the number of fingers that determines search time? To find out, we conducted haptic search experiments in which horizontal lines made of swell paper were presented to either two, four or six of the participants' fingertips. The task for the participant was to lift the finger under which they did not feel (part of) a line. In one of the conditions separate non-aligned lines were presented to the fingertips so that the number of items increased with the number of fingers used. In two other conditions the participants had to find an interruption in a single straight line under one of the fingertips. These conditions differed in the size of the gap. If only the number of items in the tactile display were important, search times would increase with the number of fingers in the first condition, but not depend on the number of fingers used in the other two conditions.

In all conditions we found that the search time increased with the number of fingers used. However, this increase was smaller in the single line condition in which the gap was large enough for one finger to not make any contact with the line. Thus, the number of fingers involved determines the haptic search time, but search is more efficient when the stimulus can be interpreted as consisting of fewer items.

PsycINFO classification: 2320

Keywords: Sensory perception; Haptic perception; Tactile perception; Proprioception; Haptic search

1. Introduction

Search experiments are generally used to get more insight into how information is processed. Many studies have been conducted on visual search. Only a few have been conducted on haptic search. However, several studies have investigated haptic object recognition. For example, Norman, Norman, Clayton, Lianekhammy, and Zielke (2004) found that the accuracy with which naturally shaped objects were discriminated was almost as precise when the stimuli were presented haptically as when they were presented visually. Behrmann and Ewell (2003) showed that participants were good at discriminating between two line patterns by tracing the lines with the two index fingers simultaneously. These results indicate that people are quite accurate in object recognition tasks in the haptic modality.

What all visual and haptic search tasks have in common is that the target must be found amongst a number of other objects. How long it takes to find a target amongst a group of distractors depends on the properties of the target in relation to the distractors. When the target is clearly different from all the other objects in one or more feature dimensions, it does not matter how many items there are in the display. It takes about the same time to find the target in the presence of various numbers of distractors (parallel search). When the difference between target and distractors is less distinctive, search times increase with the number of

* Corresponding author. Tel.: +31 20 5982573; fax: +31 20 59882529.
E-mail address: K.Overvliet@fbw.vu.nl (K.E. Overvliet).

0001-6918/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.actpsy.2007.01.001

items in the display (serial search). Although not all search theories make this strict distinction between serial and parallel processing, search tasks are generally used to determine the basic feature dimensions of perception (Duncan & Humphreys, 1989; Duncan & Humphreys, 1992; Julesz, 1984, 1986; Treisman & Gelade, 1980; Treisman & Gormican, 1988; Wolfe, Cave, & Franzel, 1989; Wolfe & Horowitz, 2004).

Lederman and Klatzky (1997) investigated the basic properties in haptic processing by presenting different kinds of stimuli to their participants' fingertips and determining how soon after contact they could find the target. They distinguished four dimensions: the material (how rough, hard or warm the material feels), abrupt surface discontinuities (a raised bar among flat surfaces or a deep hole between shallow holes), relative orientation (the target had a different orientation than the distractors), and continuous 3-D surface contours (slant or curvature). Material and abrupt surface discontinuities produced low search function slopes, indicating more or less parallel search. Relative orientation and continuous 3-D surface contours produced relatively steep slopes, indicating serial search.

A recent study (Overvliet, Smeets, & Brenner, submitted) also found that search times increased with the number of items when the target differed from the distractors in one of several spatial features, whereas the time needed for detecting a line amongst empty sensors is independent of the number of fingers. The difference was interpreted in terms of the tactile properties of the individual items. However, there is an alternative interpretation. A surface without protrusions may be considered to be a single item, irrespective of the number of fingers touching it. Thus, rather than the number of fingers, the number of 'objects' may be critical. The results of Lederman and Klatzky (1997) and Overvliet et al. (submitted) could be explained in terms of the number of items rather than of the number of fingers used. If so, items must be recognized by their material properties or by the way in which they can be combined to form surfaces.

Knowing what you are going to feel may also help to bind properties into a single item, for example, when carrying a book, we automatically perceive its edge as a single shape and not as four objects touching our fingertips. Imagine that the book has some damage on one edge of the cover. When we hold the book in our hand we will feel the ripped paper. Does the fact that we know how it feels to touch a book help us to detect a possible deviation from the expected shape faster than when we touch an artificial set of 'unrelated' objects?

We hypothesize that the impression of exploring a single complete object will lead to a more efficient search pattern. To investigate this, we compared haptic search when separate small lines were presented to the participants' fingertips with haptic search when a single longer line was used as a stimulus. The task for the participants was to indicate which finger did not have a line under it. When a single line was used this is equivalent to finding the gap in the line. Our hypothesis yields predictions that are between two possible extremes. If only the number of objects is relevant, we expect search time not to increase with the number of fingers in this condition. However, if only the number of fingers is relevant, search time will increase with the number of fingers that explore the single line in the same way as it does for the separate small lines.

2. Method

2.1. Participants

Ten participants took part in the experiment, six male and four female, with an age range of 23–48 years. Two of them stated to be left-handed. Most of the participants were familiar with psychophysical experiments.

2.2. Stimuli and apparatus

The setup consisted of six force sensors, which were designed to have a piece of ZY®-TEX2 Swell paper (Zychem Ltd., Cheshire, England) attached to them. The items were horizontal lines with a line width of 1.4 mm, which protruded about 1 mm from the surface of the swell paper. Each sensor could be positioned separately to accommodate different hand sizes and stimulus positions. The sensor measured whether there was a finger on top of it. To be able to determine reaction time, the apparatus was connected to a computer. The sample rate was 60 Hz. A curtain was placed between the participant and the apparatus to prevent the participant from seeing the display. The apparatus is shown in Fig. 1A.

2.3. 'Separate lines'

In the first condition, the stimulus consisted of separate lines that were positioned beneath the participants' finger pads when in a comfortable (natural) position (Fig. 1B). Each item was a separate 2 cm horizontal line. The target was a piece of swell paper that did not contain a line.

2.4. 'Wide gap'

In the second condition, the stimulus was a 14.5 cm line. The 2 cm wide sensors were spaced with a distance of 0.5 cm between them to avoid fingers touching the sensor that was used for the adjacent finger. The target was a 2 cm gap in the line. Participants now had to adjust their finger positions to the line (Fig. 1C).

2.5. 'Narrow gap'

This third condition was identical to the second except that the participant could feel the edges of the gap at the target. The size of the gap was 50% of the width of the participants' index finger (the used gap size was 0.7 cm, 0.8 cm, or 0.9 cm).