Vision Research 126 (2016) 52–58

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Perceptual grouping determines haptic contextual modulation

K.E. Overvliet [a,b,*,1], B. Sayim [a,1]

[a] Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Tiensestraat 102, 3000 Leuven, Belgium
[b] Faculty of Human Movement Sciences – Research Institute MOVE, VU University, Van der Boechorststraat 9, 1081 BT Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 20 December 2014
Received in revised form 12 April 2015
Available online 14 May 2015

Keywords:
Perception
Gestalt
Grouping
Haptic
Tactile
Contextual modulation

ABSTRACT

Since the early phenomenological demonstrations of Gestalt principles, one of the major challenges of Gestalt psychology has been to quantify these principles. Here, we show that contextual modulation, i.e. the influence of context on target perception, can be used as a tool to quantify perceptual grouping in the haptic domain, similar to the visual domain. We investigated the influence of target–flanker grouping on performance in haptic vernier offset discrimination. We hypothesized that when, despite the apparent differences between vision and haptics, similar grouping principles are operational, a similar pattern of flanker interference would be observed in the haptic as in the visual domain. Participants discriminated the offset of a haptic vernier. The vernier was flanked by different flanker configurations: no flankers, single flanking lines, 10 flanking lines, rectangles and single perpendicular lines, varying the degree to which the vernier grouped with the flankers. Additionally, we used two different flanker widths (same width as and narrower than the target), again to vary target–flanker grouping. Our results show a clear effect of flankers: performance was much better when the vernier was presented alone compared to when it was presented with flankers. In the majority of flanker configurations, grouping between the target and the flankers determined the strength of interference, similar to the visual domain. However, in the same width rectangular flanker condition we found aberrant results. We discuss the results of our study in light of similarities and differences between vision and haptics and the interaction between different grouping principles. We conclude that in haptics, similar organization principles apply as in visual perception and argue that grouping and Gestalt are key organization principles not only of vision, but of the perceptual system in general.

1. Introduction

In order to efficiently process information from the environment, the perceptual system has to organize the perceptual input across space and time. For example, the perceptual system determines what parts of a visual scene belong together (grouping), and what is figure and ground (figure–ground organization). The nature of perceptual organization is at the very heart of Gestalt psychology (Koffka, 1922; Wertheimer, 1912, 1923). One of the major challenges of Gestalt psychology is the quantification of its principles. Here, we use contextual modulation as a tool to quantify perceptual grouping in the haptic sensory modality.

Perception of an object is known to strongly depend on its (spatial and temporal) context. For example, finding a friend in a busy train station is much more of an effort than in an uncluttered environment. Context effects also occur with very simple stimuli. For example, in vision, vernier offset discrimination strongly deteriorates, when the vernier is flanked by lines (Fig. 1A; e.g., Westheimer, Shimamura, & McKee, 1976). In audition, both melodic and rhythmic context affect recognition of embedded tones (Jones, Boltz, & Kidd, 1982). Hence, in these – and other – modalities, the perceptual system integrates information over both space and time.

In visual perception, the effect of context is usually explained by local interactions between target and context. For example, the deteriorating influence of flankers on target discrimination has been explained by lateral inhibition (e.g., Solomon & et al., 2004; Westheimer & Hauske, 1975), and spatial pooling (e.g., Badcock & Westheimer, 1985; Wilkinson, Wilson, & Ellemberg, 1997). However, a growing number of studies investigating context effects in visual perception show that the local context of a target is not a good predictor of performance. Rather, the entire (global) stimulus configuration has to be taken into account to predict performance (e.g. Livne & Sagi, 2007; Malania, Herzog, & Westheimer, 2007; Manassi, Sayim, & Herzog, 2012; Sayim, Westheimer, & Herzog, 2008, 2010). In particular, we showed that vernier

* Corresponding author at: University of Hamburg – Department of Biological Psychology and Neuropsychology, Von-Melle-Park 11, 20146 Hamburg, Germany.
[1] Joint first authors.

http://dx.doi.org/10.1016/j.visres.2015.04.016
0042-6989/

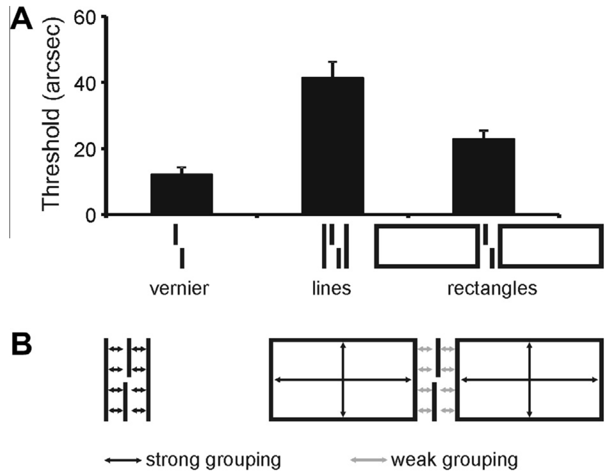

Fig. 1. (A) Contextual modulation of vernier thresholds in the visual domain. When a vernier is flanked by lines, performance deteriorates. When the lines are part of rectangles, i.e., grouped in a good Gestalt, performance improves compared to the lines alone (adapted from Sayim, Westheimer, & Herzog, 2010). (B) Grouping between a vernier and flanking lines is strong. Grouping between flanking lines and the vernier is reduced when the lines are part of rectangles. Grouping between the parts of the rectangles is strong.

discrimination is determined by the grouping of the target with the flankers by various grouping cues, such as size (Malania, Herzog, & Westheimer, 2007; Manassi, Sayim, & Herzog, 2012), color, contrast polarity, and depth (Sayim, Westheimer, & Herzog, 2008), good Gestalt (Sayim, Westheimer, & Herzog, 2010), and regularity (Manassi, Sayim, & Herzog, 2012). For example, single lines flanking a vernier target strongly deteriorated performance. Integrating these (local) lines into (global) rectangles, i.e., grouping the lines into a shape, improved discrimination (Fig. 1A; Sayim, Westheimer, & Herzog, 2010). We proposed that when the lines were parts of rectangles, they ungrouped from the vernier target, reducing interference by the flanking lines (for illustration, see Fig. 1B). Such influence of target–flanker grouping on performance shows that purely local mechanisms cannot explain these context effects (see also, Manassi, Sayim, & Herzog, 2013).

An important question is whether grouping mechanisms are specific to vision or a characteristic of the perceptual system in general. Grouping effects, for example, have also been shown in other modalities, such as auditory (Bregman & Campbell, 1971) and haptic perception (Chang, Nesbitt, & Wilkins, 2007a, 2007b; Frings & Spence, 2013; Gallace & Spence, 2011). For example, we recently found that grouping by proximity influenced the speed of haptic enumeration (Overvliet & Plaisier, in press; Verlaers, Wagemans, & Overvliet, 2015) and the accuracy in haptic contour detection (Overvliet, Krampe, & Wagemans, 2013). Similarly, good continuation and similarity improved haptic search performance (Overvliet, Krampe, & Wagemans, 2012; Van Aarsen & Overvliet, in preparation). These results suggest that similar principles as in the visual modality applied to the haptic modality. However, all these studies could be explained by local grouping, without the need to integrate spatio-temporal information of the whole stimulus display. The question thus remains whether grouping effects that cannot be explained by local similarity occur in haptics, for example, when global features favor different ways of grouping than local features.

The haptic system derives sensory information via two different input channels, touch (on the skin) and proprioception (location of the limbs relative to each other and in space). The touch input stems from the mechanoreceptors and thermo receptors embedded in the skin. The proprioceptive input is derived from mechanoreceptors and muscle spindles that are embedded in the muscles, tendons and joints. In order to, for example, determine the location of an object or its edges, we need to interact with the object to integrate proprioceptive with tactile information (Lederman & Klatzky, 2009). This integration process takes about 250 ms (Overvliet, Azañon, & Soto-Faraco, 2011) and requires several separate brain areas (Azañon et al., 2010). Because of the active and multisensory nature of the haptic sense, its relation to the Gestalt theory and grouping principles is particularly interesting. The number (10 fingerpads vs. 2 retinas) and positions (relatively flexible vs. fixed) of the haptic and visual sensors and the size of the perceptual field (small vs. large) is one of the major differences between visual and haptic perceptual processes. Visual perception allows parallel processing, while in the haptic modality, we need to move our hands and fingers in order to extract the shape of an object (Lederman & Klatzky, 1987) or to obtain information about spatial relations between objects; this is a serial process.

In the current study, we investigate the influence of different contextual configurations on the perception of a haptic target stimulus (Fig. 2). Participants were presented with haptic verniers consisting of two short lines with an offset between the two (similar to the visual domain; Fig. 1). Participants indicated the offset direction of the vernier. The vernier was either presented alone or flanked by line configurations. First, we investigated whether the basic effect of close-by flankers in the visual modality, i.e. a deterioration of performance by the flankers, also occurred in haptics. Next, we were interested whether grouping of flankers had a similar effect on haptic vernier discrimination. We hypothesize that, if the stimulus as a whole is taken into account, similar flanker effects will be found as in the visual counterpart: flankers that ungroup from the target will interfere less with vernier discrimination compared to flankers that group with the target. On the other hand, if only local information is used, the global flanker configuration would not be crucial and we will find similar deterioration of vernier discrimination with flankers that are locally similar.

We found that grouping and the global configuration of target and flankers determined haptic vernier offset discrimination, similar to the visual domain. Interestingly, flanking rectangles only reduced interference compared to single lines when they were narrower than the target, and not when they were of the same width as the target. We suggest that different weightings of grouping cues in the haptic and visual domain may underlie this finding. As proposed earlier (Sayim, Westheimer, & Herzog, 2010), our results show that contextual modulation can be used as a tool to quantify Gestalt laws – at least in the visual and haptic domain. Differences and similarities of vision and haptics reveal in how far (specific) grouping principles are features of the perceptual system in general.

2. Method

2.1. Participants

Nineteen volunteers from the university community were paid for their participation in this study (mean age 21.7 ± 2.5 years, 18 right-handed, 12 females). We measured both tactile sensitivity (mean score 4.66 ± .41; maximum score is 5) and moving and static 2-point discrimination (mean score 2.21 ± .42 mm and 2.79 ± .63 mm, respectively) by using the Touch-Test® Sensory Evaluators and the Touch-Test® Two-Point Discriminator (North Coast Medical, Inc., USA). None of the participants had a score below “normal” as indicated by the Touch-Test® manufacturer. The study was conducted in line with the ethical principles regarding research with human participants as specified in The Code of