Role of Force Cues in the Haptic Perception of Length

Pierre Wydoodt[1], Edouard Gentaz[2]

[1] FranceTélécom R&D, 38-40 rue du Général Leclerc,
92794 Issy Moulineaux Cedex 9, France
pierre.wydoodt@rd.francetelecom.fr
[2] CNRS, Laboratoire Cognition & Développement, Paris V, (UMR 8707),
71 avenue Edouard Vaillant, 92774 Boulogne-Billancourt Cedex, France
Edouard.Gentaz@umpf-grenoble.fr

Abstract. This study examines whether the force cues play a role in the haptic perception of length. The effect of two dynamical perturbations –“viscous” (opposition force) - vs. –“fluid” (traction force) - on the haptic perception of a 10-cm length virtual segment was tested in blindfolded adults. The results revealed that a viscous perturbation during finger movement leads to an underestimation of the length whereas a traction perturbation leads to an overestimation. Results suggest that muscular force produced for exploratory movement is used as cue in length haptic estimation.

1 Introduction

Haptic perception of length depends on geometrical and forces cues. Geometrical cues can be limited to all visited positions during finger exploration, whereas force cues contains all forces implied in the exploration (contact forces, inertia or all other external forces). These two types of cues are correlated but it has been commonly assumed that haptic perception of space relies on stimulus geometry alone [1].

Classical haptic studies have shown that the perception of length obviously varies according to the physical length of a segment (geometrical cues). In haptics, an increase in the physical value of the stimulus produces a proportional increase in the perceived size. However, this psychophysical function is influenced by the response mode. Thus, the function is linear with an exponent of 1 when the estimation is given via the space between the two index fingers actively placed at each end of the stimulus [2] or via the movement along the stimulus of just one index finger or whole hand [3] [4]. Finally, the psychophysical function is linear and its exponent is 0.885 when the participants are asked to reproduce the length of the segments (made up of raised dots) with the same index finger [5].

The role of force cues in the haptic perception of length has not yet been investigated. However, in a connected field, a recent study revealed that force cues overcome object geometry on the haptic perception of shape [6]. The main goal of the present study was to examine whether the force cues also play a role in the haptic perception of length. To address this question, we studied the effects of two dynamical perturbations –"viscous" (opposition force) - vs. –"fluid" (traction force) - on the haptic perception of a 10-cm length virtual segment.

2 Method

Participants The participants were 12 right-handed adults. Informed consent was obtained from all participants.

Experimental procedure Blindfolded participants sat in front of a table on which lay the force feedback apparatus. Each put the right index into a thimble that was mounted at the extremity of the device. At the beginning of each trial, the device produced a force that guided the participant's finger to the start point of the haptic virtual segment (consisting in a cylindrical symmetry force field). A beep indicated the beginning of the exploration of the segment. During this phase, the device first allowed the participant to move the fingertip along a 10-cm length reference segment [LR] from left to right and back (once only in each direction). Then, the participant explored in the same way the second test length [LT] which varied in length from {-2,-1, -0.5, 0, 0,5, 1, 2} cm relative to LR. Moreover, during the exploration of the LT, a dynamic perturbation was introduced. The participants were asked to estimate whether the LT was longer or shorter than the LR by pressing one of two buttons with their left hand. Each pairs (7 were possible) were repeated 20 times. In total, there were 140 trials randomly ordered in one session.

Two dynamical perturbations were proposed: "viscous" or "fluid". The viscous perturbation was a linear viscosity ($F(\mathbf{v})=-\lambda_1.\mathbf{v}$; $|\lambda_1|=3\ N.m^{-1}.s$). The fluid perturbation consisted in a complex negative viscosity. ($F(\mathbf{v}) = -|\lambda|.\mathbf{v}.(\mathbf{v}-v_1).(\mathbf{v}-v_2)$.; $v1=0.1\ m.s^{-1}$; $v2=0.6\ m.s^{-1}$ and $|\lambda|\approx 16.6$ (S.I.) Thus, negative viscosity is maximum ($F\approx+0.5N$) around a velocity of $0.4\ m.s^{-1}$

Six participants were tested in two sessions: an experimental session with the viscous perturbation and a control session with no perturbation. Six other participants were also tested in two sessions: an experimental session with the fluid perturbation and a control session with no perturbation. The order of the two sessions (perturbed and control) was counterbalanced across participants.

Data Analysis Reporting the number of "larger than" response for each different length of LT by participant gives a increasing curve. PSE is given by the value of LT when the number of "larger" responses is 50% of trials for this LT (n=20). No function was used as model to fit results, but PSE were extracted with the first intersection with the y=50% line. Thus two PSEs were calculated for each participant: Control PSE (PSEc) and Perturbed PSE (PSEp). Finally, individual displacement of PSE (PSEdisp), calculated by participant, is the difference between perturbed PSE and control PSE.

3 Results

Global analysis Participants underestimated the length in the viscous perturbation condition whereas their estimations were accurate in the control condition (Table 1). However, the mean PSE observed in control and perturbed conditions did not differ significantly (two-tailed *t* test; $p > .25$). By contrast, participants overestimated the length in the fluid condition whereas their estimations also were accurate in the control condition. The mean PSE obtained in control and viscous conditions differed significantly (two-tailed *t* test; $p < .01$).

Table 1. Mean (n=6) perturbed and control PSE (M±SD) for the two perturbations (viscous and fluid), and mean PSE displacement. All values are in mm

	Perturbed PSE	**Control PSE**	**PSE displacement**
Viscous	2.77 ± 11.84	-0.83 ± 7.45	3.60 ± 5.11
Fluid	-3.33 ± 1.86	-0.07 ± 1.66	-3.27 ± 1.86

Individual analysis The large intra-subject variability observed in the global analysis leads us to perform an individual analysis. To examine effective displacement of PSE of each participant, the intra-individual PSE difference has been calculated. PSE displacement is calculated from individual expression $PSE_{/Perturb.} - PSE_{/Control.}$

Figure 1 shows individual PSE displacements for the two conditions. In the fluid condition, all PSE displacements are negative (m=-3.27 mm): one-tailed *t* test comparing the mean value of PSE with zero showed that this perturbation was significant ($p < .01$). In Viscous condition, all PSE displacements but one are positive (m=3.6 mm): one-tailed *t* test showed that this perturbation was not significant ($p = .15$). This absence of significativity was only due to participant n°3 ($PSEdispl_3 = -3.0$ mm). Moreover, the precision of this participant was very weak in control condition (control $PSE_3 = -15.0$ mm).

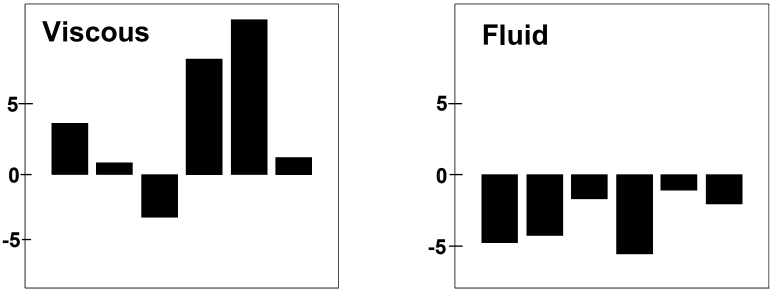

Fig. 1. PSE displacement (in mm) by participants for *(left)* viscous and *(right)* fluid perturbations.