Does Active Exploration Suppress Tactile Flow Perception?

Davide Dente* Enzo Pasquale Scilingo* Nicola Sgambelluri* Antonio Bicchi*
(*)Interdepartmental Research Center "E. Piaggio", Via Diotisalvi 2, 56100 Pisa, Italy
E-mail: { davide.dente, e.scilingo, n.sgambelluri, bicchi}@ing.unipi.it

Abstract

In this paper we report on results of a set of tests in which a group of subjects were asked to trace a straight line with the forefinger while actively scanning over a textured surface. A pattern of bumped dots, randomly distributed, and a diagonal striped pattern were used in order to investigate the occurrence of misleading perceptions based on the aperture problem of tactile flow during an active exploration. Obtained results are compared with findings achieved from a previous experiment based on passive exploration.

1. Introduction

In a previous work [1] authors performed a collection of psychophysical experiments aimed at reproducing visual illusions based on optic flow [3] [4] in tactile passive form, through a passive exploration. In particular it has been experimentally proved that when subjects passively touched with their forefinger a diagonal striped pattern moving along a horizontal direction, they perceived an illusory motion direction perpendicular to the inclination of ridges. This tactile misperception is in agreement with the well known visual barber pole illusion based on the aperture problem of the optic flow.

This paper aims at investigating how cutaneous perception is influenced by active exploration of a finger over a textured surface and verifying the occurrence of misleading perceptions based on the aperture problem of the analogue of optic flow in the tactile domain, which we called tactile flow. Our hypothesis is that when kinematical cues are added to cutaneous information due to the active movement of the finger, misperception could be reduced, or somehow "suppressed".

2. Psychophysical Experiment

2.1 Experimental Setup

A PHANToM® Desktop [6] (PHD) from SensAble Technologies was used to perform the experiments. The PHD allowed us to easily evaluate and store kinaesthetic variables (position and velocity) of the hand during active exploration.

Fig. 1 – Experimental setup during the training (left) and a zoom view while a volunteer touches a 45° ridges pattern during test (right).

2.1 Misperceptions during active exploration - Methods

Fifteen subjects (6 females, 9 males) volunteered to participate in the experiments. Their ages ranged from 22 to 36 years, with an average of 28 years, all highly cultured and in good health.

All participants were naive of the specific purpose of this experiment. The PHD was used to record the trajectory described by subjects' hand.

The right hand of subjects was linked to the PHD end-effector by means of a special glove, leaving the forefinger (***Fig. 1***) free to move. Two textured pads were used: the first one presented a random distribution of bumped dots, with a bump height of less than 0.5 mm (dots pattern) and 1 mm wide. The second pattern presented parallel ridges inclined by 45 degrees with respect to horizontal line. The ridges were less than 0.5 mm high, 1 mm wide and separated by grooves 0.85 cm wide. Both patterns were suitably obtained by impressing a plastic transparent slide.

Subjects were asked to follow a horizontal straight line (x axis, frontal) from left to right, freely moving their finger within a workspace of 29 cm (length) x 12 cm (width). The experiment was split into two stages: training and test. During the training phase, subjects were asked to repeatedly move their forefinger along a horizontal straight line over the dotted patterns for a time lapse of 1 minute. They could observe the trajectory traced out on a PC monitor such as to correct possible deviations and acquire familiarity with the tactile task. No instructions were given about movement speed, and subjects could freely move the finger along the path until the end of pattern. A

lubricant was used to reduce friction between finger and patterns in order to minimize the stimulation of Ruffini corpuscles [1]. In the second phase, the subjects were blindfolded and asked to perform the same task again, this time on both different patterns. Each subject was required to repeat each trial twice.

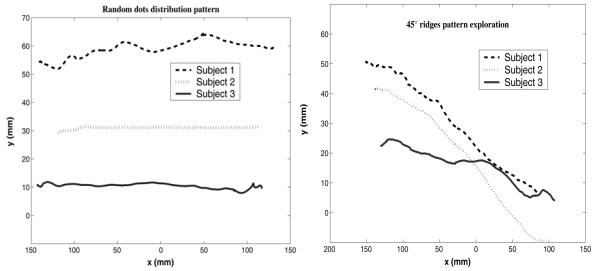

Fig. 2 – Trajectories traced out by three different subjects over a dots random distribution pattern (left) and a ridges pattern (right) without visual feedback.

2.3 Experimental Results

For the sake of simplicity and clearness, only results from three subjects have been depicted. ***Fig. 2*** reports the trajectories traced out by three subjects over the dot pattern (left) and over the diagonal striped pattern (right), respectively. In order to improve the readability, the curves have been arbitrarily shifted.

Parameters	***Dots pattern***	***diagonal pattern***
Y-Coordinate Maximum Excursion (max – min)	9.023 mm	16.563 mm
Average on max slope	0,5264	0,09
Average on min slope	-0,6320	-0,662
Average slope	0,0239	-0,31.

Tab. 1 – Experimental averaged results relative to all subjects with dots and diagonal ridges pattern .

Tab. 1 reports some significant parameters extracted from the curves traced out by the subjects during the active exploration over dots pattern and diagonal striped pattern, respectively. It is worthwhile pointing out that when subjects moved their forefinger over the dot pattern, they followed nearly straight trajectories with a little ripple along y-axis.
Comparing obtained results with findings from the previous passive experimental session, we can state that when the pattern does not present a privileged direction in the texture, i.e. dot pattern, then subjects are able to recognize the actual motion direction in passive mode and follow a quite straight line in active mode. When a diagonal striped pattern was used misperception is still present but more attenuated with respect to passive exploration. The average angle of the linear trend calculated on the responses of all subjects, in active touch, was -18 degrees with respect to horizontal line, against the about -45 degrees of the perceived motion direction during passive experiments.

3. Discussion and Conclusion

Experimental results can be interpreted in terms of tactile flow elaboration. The presence of differences in performance between active and passive movements in complex patterns is still an open question [5]. The aim of our experiment was to verify whether the active exploration could impinge on the tactile misperception. Previous experiments [1] have showed that when a textured pad having a random distribution of dots comes into contact with the fingertip and it is moved in a passive way does not give rise to misperceptions of the motion direction, while the texture with diagonal ridges induces illusions according to the aperture problem of the tactile flow. The experiments here performed in active modality, confirm these results. Nevertheless, the illusory perception here is less pronounced and this could be due to the fact that additional kinesthetic cues due to active movement reduce misleading perception.

However, these results represent a good starting point to perform more accurate tests to better quantify differences between passive and active tactile illusions and investigate thoroughly the role of interaction between kinesthetic and cutaneous cues.

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