Detecting Signals in Correlated Motion of the Fingers

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Abstract

Normally, when we explore or manipulate objects more than one of our fingers will come into contact with and move over a surface. Movement of the object or our fingers may give rise to different motion at each finger yet we retain a sense of a single object. We have investigated this by examining how correlated motion across the fingers may help detection of a kinaesthetic stimulus. We have found lowered thresholds for detecting stimuli in the presence of positively correlated background movement compared to negatively or uncorrelated background movement. In future experiments we will investigate the effect of positive correlation by varying time differences between the movements at the fingers.

1. Introduction

Our fingers receive ordered input containing correlated time or spatial relationships. For example as we grasp a cup with one hand, the information from each of our fingers may tell similar things as the cup may be fairly uniform in its compliance, texture and temperature. Additionally, because our fingers can move around the cup, e.g. feeling it's shape, different fingers may encounter the same part of the object at different times. The information from our fingers can also be useful for action. For instance slipping sensations across the fingers could tell us that we have not grasped the cup hard enough and will allow us to adjust the force we are exerting. It is important to note that information from our fingers may also be related across the hands. Everyday we use both hands in a co-operative effort for manipulating and perceiving our world. As we stroke a pet our hands may receive information about the texture, form and movement of the animal. The kinds of sensations we receive at each hand and all our fingers should be related as our hands enclose the animal. The use of relationships between information coming from both of our hands helps us form whole percepts and understand our touched world.

Movement of the hands and fingers plays a key role in tactile perception. The movement can be self imposed, imposed by external objects or some mixture of the two. In any of these cases the movement-related sensations we experience at the fingertips tend to be ordered, and this order can come from the following sources. Firstly, hand movements during haptic exploration have been shown to be highly systematic and can be grouped into a number of distinct classes [2]. The selection of a particular class of exploratory movements was shown to depend on the kind of information being sought. This order in our movements can in turn impose an order in the form of sensation and in the changes in sensation we might receive from our fingers. For instance, while seeking texture information, we might make backward and forward rubbing motion across a surface. In this movement each finger may cover areas already touched by other fingers after an amount of time determined by the speed with which the hand is moving, thereby creating a relationship between the sensations at each finger.

Secondly, movements imposed on the hands, when they are in contact with a single source, will generate related sensations at the contacting points. As someone attempts to pull a book that we are holding with both hands, the motion information coming from our hands will be highly correlated. Unlike our other sensory organs, our limbs and specifically our hands are able to change their relative positions. Yet despite this flexibility, we are able to make sense of the tactile sensations we experience even in the absence of vision. It is possible that tactile perception is affected by a sense of the relative position of the two hands. Support for this comes from a study [1] showing that judgements made about passively received tactile signals are modulated by the spatial distance between the tactile receptors in the real world.

Evidence for the use of correlation across bilateral channels in another modality comes from studies of auditory perception. In particular experiments examining the effect of binaural masking level differences, where the masked threshold of a signal can be lower when listening with two ears than when listening with one. Presenting a signal (e.g. a tone) and masking noise (e.g. white noise) in one ear, it is possible to adjust the level of the tone so that the tone is just masked by the noise (it's masked threshold). It is possible to lower this threshold by introducing noise (from the same noise generator) to the other ear. In this case the tone can be released from it's masker and becomes audible again [3]. Including the signal in the previously signal free ear eliminates this effect, once again masking the signal.

We have used an analogous paradigm to investigate whether people are able to make use of correlation between bilateral tactile information. We introduced pseudo-random background motion (noise) to the index fingers of each hand and varied the relationship between this noise on both hands. Subjects had to report whether a one-second long signal (a gaussian form) embedded in the noise was on their left or right hand. In principle it might be possible, by comparing the noise on one hand to the noise on the other, to reduce the effect of the background noise and make the signal easier to spot. If this were the case then we would expect reduced discrimination thresholds for the signal when it was embedded in correlated and negatively correlated noise, compared to when it was embedded in uncorrelated noise.

2. Methods

2.1. Subjects

10 subjects, 4 male, 6 female participated in this experiment after giving informed consent. Their ages ranged from 23 to 35 years (mean ± standard deviation, 27.9 ± 3.9). Based on self report, 8 subjects were right handed and 2 left-handed. All the subjects were paid for the time spent in the experiment.

2.2. Equipment

A set of linear motors in the form of an array was used to move the subject's index fingers. The array comprised a set of spaced actuators each with a surface diameter of 23 mm. There was 30 mm spacing between actuators in all directions. During the experiment, subjects were seated in front of the array, with their forearm resting on its static surface. They were asked to lightly rest each index finger on one of two raised, adjacent actuators. The rest of the hand remained flat on the static surface.

2.3. Procedure

Each trial lasted 4 s during which random background noise was presented to the subjects' index fingers. The contacting actuators moved the subjects' fingers through one of series of pseudo-random movements. After 2 s of movement a height increase appeared on one of the fingers. This signal lasted 1 s and had a gaussian form. At the end of the trial subjects used a left or right foot pedal response to indicate whether the signal was on the left or the right finger. Auditory feedback was provided as to whether the response was correct.

We manipulated the correlation between the background noise movements on the left hand and those on the right hand. The movements on the hands could be positively correlated, negatively correlated or uncorrelated. The noise movements had a range of 11 mm and an average absolute velocity of 35.4 mm/s. The actuators took 100 ms to move between positions.

Adaptive psychophysical staircases were used to determine the 79 percent correct threshold for discriminating whether a signal was presented to the left or right index finger. Each subject completed two staircases for each condition. The staircases were interleaved. The experiment lasted one hour and complete data sets were collected for all 10 subjects. The results of subject 8 are shown below.

Figure 1: Staircases for subject 8

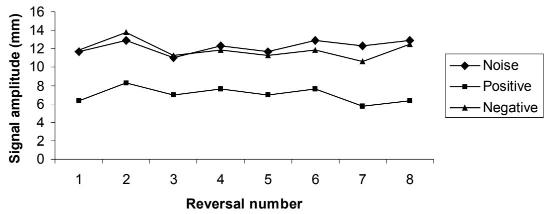

Figure 1 plots the signal amplitude on each trial. Each curve corresponds to one of the 3 conditions (i.e. a staircase) for subject 8. The curves start with increasing signal amplitude following an error. When a subject makes 3 correct responses the direction of the change in signal size reverses and the signal decreases again. The figure shows that these reversals occur about lower signal amplitudes for signals in positively correlated movements compared with signals occurring in negatively and uncorrelated movements.

3. Results

Analysis of variance revealed that there was an overall main effect of correlation $F(9,18)=13.412$ $p <0.01$. There was no reliable difference between the 2 repetitions of staircases for each condition. Individual t tests indicated that the threshold for detecting a stimulus in the presence of positively correlated background noise was lower than when the movements were uncorrelated $t(9)=4.215$, $p <0.01$, or negatively correlated $t(9)=-4.911$, $p<0.01$. Performance for signals presented in negatively correlated movements was no better than that for uncorrelated movement $t(9)=-0.170$, $p>0.05$.

Figure 2: Discrimination threshold as a function of movement correlation

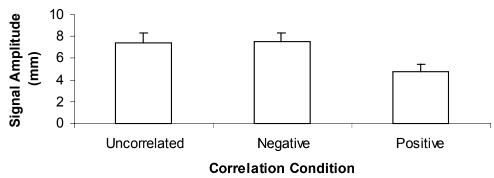

Figure 2 shows the average signal amplitude for 79 % correct performance when discriminating signals presented to the left or the right when the signal is in positively, negatively and uncorrelated movements.

4. Conclusion

This experiment shows that positive correlation between the fingers, in random background movement (noise), assists the detection of a kinesthetic signal presented to one finger. The results presented in this experiment could be achieved by a process of subtraction. This would involve subtracting information coming from one finger, from the information from the other finger. This subtraction would have the effect of cancelling the noise at each finger and allowing the signal to stand out. A model such as this may not be sufficient for dealing with all forms of correlation across the hands. For instance, theoretically, it is not possible to eliminate noise though subtraction when the noise has different amplitudes on the two fingers. However, in either situation better performance may be achieved by understanding the relationship between the simultaneous bilateral information.

Future experiments will investigate limitations on the effect of positive correlation by varying time and amplitude differences between the movements arriving at the fingers.

References

[1] Driver, J. & Grossenbacher, P.G. (1996) Multimodal spatial constraints on tactile selective attention. Attention and Performance, XVI.

[2] Lederman, S. J. & Klatzky, R. L. (1987). Hand movements: A window into haptic object recognition. *Cognitive Psychology, 19*:342-368.

[3] Moore, C.J., (1997) An introduction to the psychology of hearing. 4th edition, Academic Press