# Haptic virtual environments for blind people: further explorations with the Phantom device

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## ABSTRACT

The development of force feedback devices to add haptic information to virtual environments (VEs) has important implications for both able-bodied and disabled computer users. A study is presented in which blind and sighted participants used a PHANToM 1.0 force feedback device to feel a range of virtual grooved textures using both a thimble and stylus interaction device. Although there was no significant difference between blind and sighted participants, there were individual differences in the way the textures were perceived which have important implications for the use of haptic information in VEs. The stylus was found to produce more sensitive perception of the textures than the thimble, for both blind and participants.

## 1. INTRODUCTION

The development of force feedback devices to add haptic information to virtual environments (VEs) has important implications for both able-bodied and disabled computer users. Haptic information is the combination of what we feel through our skin (cutaneous information) and what we feel through the position and movement of our limbs and joints (kinesthetic information) (Loomis and Lederman, 1986). For able-bodied VE users, haptic information will undoubtedly add to the overall realism of the environment . But for blind people, the possibility of providing haptic information in VEs is extremely exciting. VEs which consist of haptic and auditory information have many useful and entertaining applications for blind people.

At the last conference in this series, two papers from different research groups (Colwell et al, 1998; Jansson, 1998) reported on preliminary investigations of the perception of virtual haptic information using the Impulse Engine 3000 and the PHANToM 1.5A force feedback devices respectively. Both these papers reported research which found that sighted and, in the case of the work by Colwell et al., blind participants could perceive haptic information using these devices. The studies investigated the perception of virtual textures (sandpaper like textures by Jansson and grooved textures by Colwell et al), and the identification of virtual objects and their sizes and angles of their surfaces.

One question which arises repeatedly about this type of research is whether the perceptual effects found thus far are specific to the particular devices and force feedback algorithms being used, or whether they are general to all simulations of haptic information? Unfortunately the two papers presented at the last conference did not investigate the exactly same effects, so although they used two different force feedback devices, they could not provide comparative information on this question. Some key aspects of the technical specifications for the two devices are shown in Table 1. The devices also use different algorithms for calculating the appropriate force feedback to apply at any instant and all these differences could affect the perception of virtual stimuli.

The current research has therefore extended the work undertaken with the Impulse 3000 by Colwell et al (1998) by using a PHANToM 1.0 force feedback device, in order to investigate whether perception of virtual textures and objects is similar when experienced via a different device. We have also investigated the effect of using different methods of interaction with the PHANToM device, either using a thimble (see 1) or a stylus (see Figure 2).

**Table 1**. *Some key aspects of the technical specifications of Impulse Engine 3000 and PHANToM 1.0.*

| | Impulse Engine 3000 | PHANToM 1.0 |
|---|---|---|
| **Workspace size** | 13 x 23 x 23 cm | 13 x 18 x 25 cm |
| **Maximum exertable force** | 9.0 Newtons | 8.5 Newtons |
| **Nominal position resolution** | .023 mm | .030 mm |

In the current paper, the focus will be on the perception of virtual texture, implemented as a simulation of a surface with fine grooves. Roughness of real surfaces has been studied extensively by psychologists using the psychophysical technique of magnitude estimation. This technique uses series of stimuli of known physical characteristics. Participants are asked to assign numbers to the roughness they perceive, so that if a stimulus seems twice as rough as another, it is given a number twice as large. Thus if a person calls an initial texture “20” then one which they perceive as twice as rough would be labelled “40” and one half as rough could be labelled “10”. It is well known that perception of such stimuli produces a power law such that $R = P^n$, where R is the perceived Roughness as expressed by the magnitude estimate and P is some Physical characteristic of the surface such as grit size for sandpaper. n is known as the power law exponent. If this law holds then log (R) will be a linear function of log (P) with slope n. Such a law holds for many sensations including brightness of lights, loudness of sounds and heaviness of weights ( see many perceptual psychology textbooks a fuller discussion, for example Snodgrass, Levy-Berger and Haydon, 1985). Stevens and Harris (1962) found that this law also held for roughness of sandpaper of varying grit sizes. Starting in the 1970’s, Lederman and her colleagues used more controlled stimuli of grooved plates where they could independently manipulate various parameters of the grooves. They found a power law with a small positive exponent relating roughness to groove width; and a power law with a small negative exponent relating roughness to land width (space between the grooves). So wider groove widths lead to greater perceived roughness when land is constant, but wider land widths lead to lower perceived roughness when groove width is held constant.

## 2. METHOD

*2.1 Design*

The magnitude estimation technique was used to assess the perceived roughness of a set of virtual textures, identical in their characteristics to those used by Colwell et al (1998). A completely repeated measures design was used, with one group of participants feeling all the textures with both a thimble and a stylus interaction device attached to a PHANToM 1.0 force feedback device.

*2.2 Participants*

23 people took part in the study, 10 blind and 13 sighted, aged between 19 and 54 years, with a mean age of 46. The blind participants comprised two women and 8 men, 5 of whom where blind from blind, the remaining 5 having lost their sight between the ages of 8 and 42 years (this means they are all classified as being “late blind”, having had sight, or some sight during their early development). The mean age of the blind participants was 46 years. None of the blind participants had any more that light/dark perception. These participants were recruited from the Sensory Disabilities Research Unit’s subject pool. These participants were volunteers who were only paid travel expenses to come to the Sensory Disabilities Research Unit at the University of Hertfordshire.

The sighted participants, 7 women and 6 men, were all university students, from a variety of disciplines. Their mean age was 27 years (recalculate for the 13 appropriate participants please). These participants were also volunteers, although 7 psychology students received credit towards their research methods training for participation in the study.

*2.3 Equipment and stimuli*

The study was conducted using a PHANToM 1.0 force feedback device, run from a Pentium II 400 MHz PC with 64MB RAM (see Figures 1 and 2). A thimble interaction device (see Figure 1) and a stylus interaction device (Figure 2) were both used in the study. Throughout the experiment, participants heard white noise through a set of Sanyo PH 200N headphones, so they could not use any auditory cues from the PHANToM to assist in their judgements of the textures.


**Figure 1.** *The PHANToM 1.0 with thimble interaction device*


**Figure 2.** *The PHANToM 1.0 with stylus interaction device*

The stimuli were simulations of virtual textures of a sinusoidal pattern, all with an amplitude of .1125mm and with groove widths in 10 equal steps between .675 and 2.700mm (see Figure 3).


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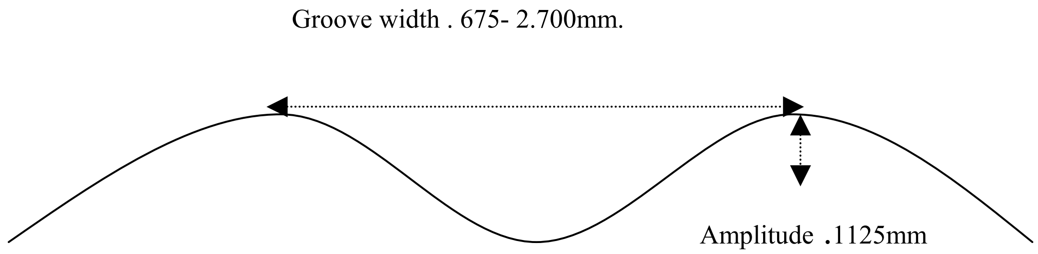


**Figure 3.** *Profile of grooved sinusoidal texture*

*2.4 Procedure*

Participants were given a brief introduction to haptic virtual reality and force feedback devices. The magnitude estimation technique to be used in the study was also explained to them. Participants were given one of the textures from the middle of the range to feel and asked to assign an initial, modulus number to it. All other textures were then scaled in relation to that modulus. Participants were given six examples of each of the 10 textures in random order, presented in blocks of 10 textures.

## 3. RESULTS

For each participant, the relationship between the "physical" characteristics of the virtual textures and their perception of those textures was investigated. The amount of variation in their magnitude estimations which could be accounted for by the characteristics of the textures is indicated by the adjusted $r^2$ values in Table 2, and the nature of the relationship between the texture characteristics and their perceptions of them is indicated by the exponent.

Table 2 shows that for the 13 sighted participants, 9 (69%) perceived a meaningful relationship between the different virtual textures using both the stylus and the thimble. Two participants (S6 and S10) perceived a meaningful relationship only using the thimble interaction device and one participant (S8) perceived a meaningful relationship on using the stylus interaction device. One participant (S12) failed to perceive the relationship with either interaction device. For the 10 blind participants, 9 (90%) perceived a meaningful relationship between the different virtual textures using both the stylus and the thimble. The remaining blind participant (B6) perceived a meaningful relationship only using the stylus.

However, although these differences are interesting for the comparison with the previous study using the Impulse Engine 3000, an analysis of variance showed that there was no overall difference in the perception of the textures by blind and sighted participants ($F_{1,22} = .66$, $p > .05$). There was a significant difference between the perception of the textures using the stylus and the thimble ($F_{1,22} = 7.31$, $p < .05$), with the mean exponent for the thimble being lower than that for the stylus, meaning that the thimble allowed less sensitivity of perception.

For the sighted participants, these results show that more people could detect the variations in the virtual textures with the PHANToM device than had been able to with the Impulse Engine 3000. Colwell et al (1998) found that only 7 out of 13 sighted participants (54%) could reliably detect the relationship between the virtual textures for the same set of textures (during the original analysis of the data from the Colwell et al study, it was discovered that there had been a error in the calibration of the Impulse, these figures reflect the re-analysis of the data with an appropriate correction factor), whereas the current study found the 69% perceived the relationship with both interaction devices, and 92% (12 out of 13 participants) perceived the relationship with one of the two interaction devices. For blind participants, results from both studies show that at least 90% of participants perceived a meaningful relationship for these textures.

**Table 2.** *Summary of results of magnitude estimations of virtual textures by blind and sighted participants.*

| | Interaction Device | | | | | |
|---|---|---|---|---|---|---|
| | Stylus | | | Thimble | | |
| | Adj. $r^2$ | Exponent | p of exponent | Adj. $r^2$ | Exponent | p of exponent |
| **Participant** | | | | | | |
| **Sighted** | | | | | | |
| 1 | .831 | -.708 | .0005[2] | .610 | -.832 | .005[2] |
| 2 | .865 | -1.081 | .0005 | .953 | -1.553 | .0001 |
| 3 | .655 | -.774 | .005 | .581 | -.470 | .01 |
| 4 | .797 | -1.06 | .0005 | .869 | -1.347 | .0005 |
| 5 | .557 | -.585 | .01 | .910 | -.887 | .0001 |
| 6 | .294 | -.573 | n.s. | .912 | -1.538 | .0001 |
| 7 | .672 | -.687 | .005 | .889 | -.601 | .0001 |
| 8 | .716 | -.696 | .005 | .143 | -.237 | n.s. |
| 9 | .647 | -.646 | .01 | .805 | -1.107 | .0005 |
| 10 | .190 | -.352 | n.s. | .601 | -.560 | .01 |
| 11 | .388 | -.389 | .05 | .338 | -.381 | .05 |
| 12 | .088 | -.036 | n.s. | .070 | .104 | n.s. |
| 13 | .872 | -.229 | .0001 | .972 | -.592 | .0001 |
| **Blind** | | | | | | |
| 1 | .751 | -.827 | .001 | .895 | -1.460 | .0001 |
| 2 | .845 | -.420 | .0005 | .906 | -.597 | .0001 |
| 3 | .584 | -.446 | .01 | .877 | -.700 | .0001 |
| 4 | .425 | -.231 | .05 | .903 | -1.486 | .0001 |
| 5 | .824 | -.730 | .0005 | .859 | -.846 | .0005 |
| 6 | .775 | -.403 | .001 | .143 | -.159 | n.s. |
| 7 | .600 | -.515 | .01 | .788 | -.607 | .0005 |
| 8 | .913 | .463 | .0001 | .928 | .608 | .0001 |
| 9 | .688 | -.514 | .005 | .889 | -.766 | .0001 |
| 10 | .648 | -.431 | .005 | .924 | -.893 | .0001 |

## 5. CONCLUSIONS

This study has shown that there are differences in the perception of virtual textures between two different force feedback devices. Given that these devices differ on a number of hardware and software parameters (see Table 1), we cannot say as yet which specific parameter might account for these differences. The results from the PHANToM device have replicated our finding from the Impulse 3000 that there are also substantial differences in the way different individuals perceive the roughness of different grooved textures. These results have important implications for the use of haptic information in VEs. For textures of the type studied here, one cannot predict how they will be perceived by different individuals. This might be particularly problematic if people are sharing a collaborative VE

It is also interesting that the thimble produced significantly less sensitive perceptions than the stylus. At a purely phenomenological level, one would have expected the opposite. The thimble seems to be a more direct way of feeling textures and objects, as one is feeling *through* the material of the thimble, whereas the stylus is less direct, as one is feeling along the stylus to the texture. However, it may be that because we are all very used to writing with stylus type devices, it is more natural to hold this device and use it as a perceptual tool as well as a writing tool. Again these results have important implications for the use of haptic information in VEs. If perception of fine-grained information such as texture is important, at the moment with the current technology, a stylus interaction device is preferable to a thimble one.

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