Preliminary Development and Evaluation of a Bovine Rectal Palpation Simulator for Training Veterinary Students

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ABSTRACT

A computer based teaching tool has been developed using haptic technology to train veterinary students to examine the bovine reproductive tract, simulating rectal palpation. The student receives touch feedback from a haptic device while palpating virtual objects. The teacher can visualise the student's actions on a screen and give training and guidance.

The teaching protocol is divided into several levels to support the progressive development of skills. Pre-clinical students are trained to orientate themselves in the three dimensional anatomical environment, to develop the correct exploratory technique and to identify key structures. More experienced students can be trained to reinforce, and further develop, existing skills.

The properties of the virtual scene were assessed by veterinary surgeons. Evaluation of the teaching tool was conducted with fourteen veterinary students. After being trained with the device, each student carried out rectal examinations and assessed the effect of haptic training. The evaluation results, although preliminary, support haptic training as a possible method for enhancing the teaching of bovine rectal palpation.

KEYWORDS: haptic, rectal palpation, education, simulator, virtual reality.

INTRODUCTION

The word "haptic" comes from the Greek word 'haptesthai' meaning to touch. The term computer haptics therefore refers to interacting with a computer through the user's sense of touch. There are an increasing number of devices that allow a user to feel objects that exist in a virtual reality environment.

The PHANToM haptic device has been developed by SensAble Technologies (Massie and Salisbury 1994). A user interacts with the device by holding a pen-like attachment, or alternatively placing his or her finger in a thimble at the end of a mechanical arm. The device then allows a user to move freely in a three dimensional environment. The PHANToM can also produce forces to restrict the user's motion. If these forces are arranged in the appropriate manner, the illusion of a physical object can be created. By subtly adjusting the forces, it is possible to create objects that feel different. For example, objects can be created with various stiffness, friction and texture parameters.

Haptic technology has been used in medical research to develop interactive training tools for minimally invasive techniques such as epidural injections (Dang *et al* 2001), surgical procedures including arthroscopy (Sherman *et al* 2001), palpation of head and neck tumours (Stalfors *et al* 2001) and rectal examination of the prostate (Burdea *et al* 1999). A generic veterinary application, which represents the first use of this technology in the veterinary field, has been in progress at the University of Glasgow since 1999 (Crossan *et al* 2002). In this project, a training environment has been developed allowing a user to interact with generic ovaries of a large animal.

Bovine rectal palpation is a procedure that requires considerable practice to develop the skills needed to identify structures. Additionally, when a student examines a cow the teacher is unable to observe what the student is palpating and can give only limited guidance. In the undergraduate curriculum there are difficulties associated with teaching rectal palpation. Access to cows is limited due to student numbers and animal welfare considerations (Penny 2002). Undergraduate students therefore perform the majority of rectal examinations while undertaking Extramural Studies (EMS). Students may perform their first examination of a cow during EMS with only minimal preparatory training in this invasive technique and it is difficult to ensure all students have the opportunity to develop adequately the required skills prior to graduation.

There is a need to investigate ways of supplementing existing methods of training. A computer-based teaching tool has the potential to provide the student with a flexible and accessible learning environment. Furthermore, training students to develop basic skills in a risk free environment is advantageous to the welfare of the cow.

MATERIALS AND METHODS

Requirements analysis

A questionnaire was circulated to veterinary surgeons. This was used to gather information about the training of bovine rectal palpation, opinions regarding the basic structure of the planned teaching environment and to identify features used during pregnancy diagnosis.

The teaching protocol was developed, based on interviews with veterinary surgeons, discussing the techniques used while examining cows and training students.

An informal discussion with a group of nine veterinary students from the University of Glasgow elicited their opinions on the problems encountered while learning rectal palpation both at the university and during EMS. They also considered the structure of the proposed computer simulator. The aim was to identify the difficulties students face and develop a teaching tool that would support their learning process.

Design and Implementation of the teaching tool

A three-dimensional pelvic scene was developed in the programming language C++ using the standard GHOST library from SensAble Technologies. This easily allows geometric objects including cubes, cylinders and spheres to be added to the scene. These objects were set to the required size, then stretched and rotated to the appropriate shape and orientation. Each anatomical structure was built from one or more of these objects and positioned in three-dimensional space.

The pelvis, which defines the boundaries of exploration, was modelled as a rectangular box, with a cylinder along the cranioventral edge representing the pelvic brim. The cervix and uterus were developed from cylinders and spheres, and placed on the pelvic floor. Ovarian structures were built from a combination of spheres, positioned caudally and slightly laterally to the tip of each uterine horn. Pregnancy was modelled by adding stretched spheres to one or both uterine horns.

The haptic properties of objects in the scene were developed using a combination of stiffness, friction and damping. This defines the resistance to the user's movement over the surface of an object and the degree of force felt in relation to penetration depth. Haptic properties are relayed to the student via the PHANToM force feedback device with a one-finger thimble attachment.

Four levels were designed to support the progressive development of skills. Each level has a haptic and graphic representation of all the objects in the scene. The student, prevented from seeing the graphics on the computer screen, explores the scene purely with touch feedback. Level 1 has only the cervix in the midline on the floor of the pelvis. The student is trained to develop a basic exploratory technique, sweeping the hand down, from side to side and then cranially over the pelvic brim. Level 2 contains a non-pregnant uterus and ovaries (Figure 1).

Figure 1. Level 2: Graphic representation of a non-pregnant uterus with a corpus luteum on the left ovary (this is the view seen by the teacher).

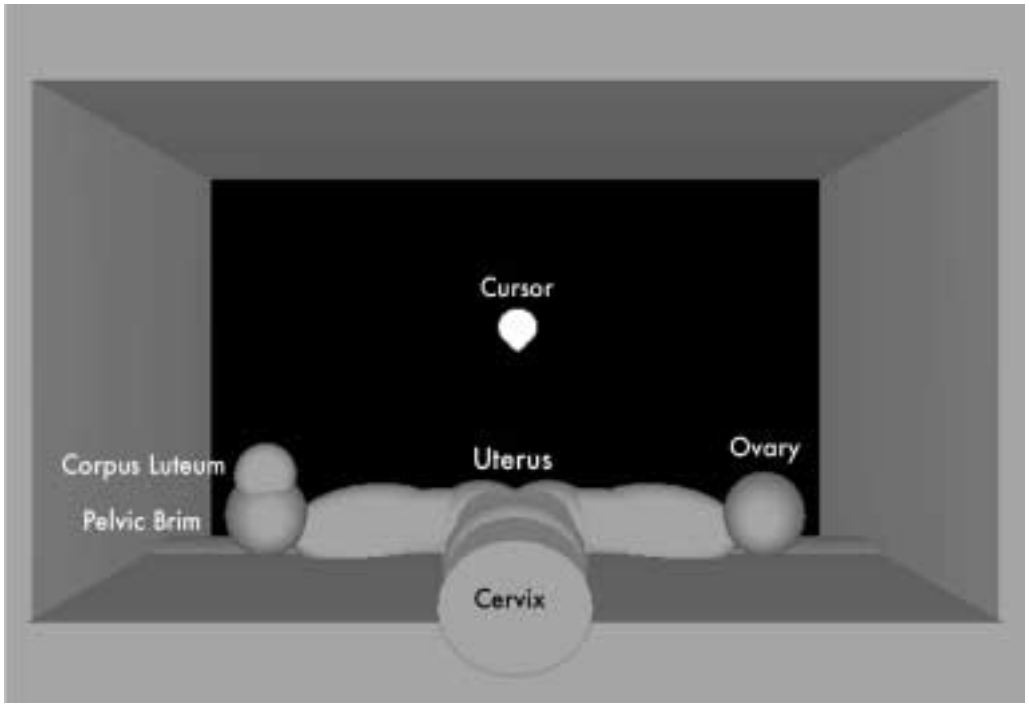
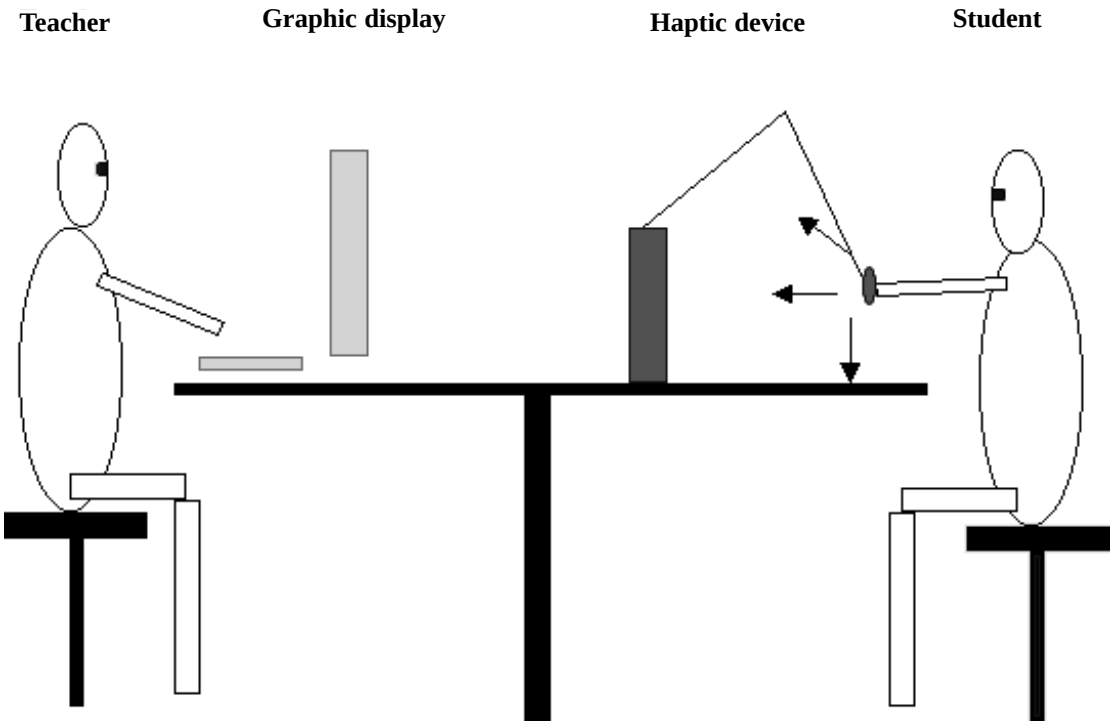


Figure 2. Illustration of the teacher guiding as the student palpates the virtual bovine reproductive tract.



The student is taught to orientate in the three dimensional anatomical environment and to identify key structures, such as the uterine body. These levels were designed for training pre-clinical students prior to their examination of real cows. The student is encouraged to develop awareness of the position and to describe the distinctive properties of structures palpated.

Levels 3 and 4 include options, selected from dialogue boxes, for a range of ovarian structures and stages of pregnancy. These levels are appropriate for more experienced students to build on existing skills. Additionally, these levels have the potential to allow students to experience a wide range of scenarios.

The haptic programme was designed to be easy for the teacher to use and is launched from a dialogue box accessed from a desktop shortcut. The teacher selects a level appropriate to the student's skills. The student's exploration in the virtual environment is represented by a cursor in the graphic scene (Figure 1) and while following this, the teacher gives guidance (Figure 2).

A fibreglass model of the rear half of a cow was constructed and placed over the haptic device to create a more realistic environment. The student interacts with the PHANToM thimble attachment through a cuff representing the anal sphincter.

Evaluation

Veterinary Surgeons

During development each anatomical structure was assessed and adjusted to be representative of a cow, in view of the variation dependant upon the age and time post calving. Nine veterinary surgeons took part in a more formal evaluation. All had large animal experience as well as being involved in veterinary training during EMS and the Final Year rotation for University of Glasgow veterinary students. The veterinary surgeons had a range of computer skills and included novice users. Each veterinary surgeon assessed the haptic properties of the bovine anatomical structures, the graphics, the teaching protocol, the haptic device and some non-computer aspects.

The main part of the evaluation involved assessment of the haptic properties. The veterinary surgeon palpated each structure assessing the shape, size and feel, as good, adequate or inadequate. Comments for improvement were recorded.

Evaluation

Veterinary Students

Evaluation of the haptic simulator as a teaching tool was conducted with fourteen veterinary students. An experienced veterinary surgeon instructed each student during the exploration of the virtual environment, following a predetermined teaching format. After being trained with the device each student carried out rectal examinations with veterinary surgeons on farms. The students were asked to assess whether they considered their skills had improved as a result of haptic training, completing a questionnaire and to comment on this technology as an adjunct to existing teaching methods.

RESULTS

Requirements Analysis

Questionnaires

Table 1 shows a summary of the results from thirty-seven questionnaires completed by veterinary surgeons. Rectal palpation was considered to be a difficult procedure for students to learn and an important skill, even with the widespread use of ultrasound scanners. In the initial design, the pelvis was modelled as a box and the majority (twenty-seven) considered this to be at least adequate. Training students to locate the cervix on the floor of the pelvis was considered to be a useful starting point and visualising the student's progress on a screen was considered to be helpful.

Table 1. Summary of results from questionnaires completed by thirty-seven veterinary surgeons relating to the training of veterinary students and rectal palpation.

Do you think students find rectal palpation :			
Very Difficult	Difficult	Easy	Very Easy
22	15	0	0
With widespread access to ultrasound scanners teaching rectal palpation is :			
Very important	Important	Not important	No longer necessary
29	8	0	0
Modelling the pelvis initially as a box would be :			
Completely adequate	Adequate	Just adequate	Not adequate
7	20	8	2
Training students to start by locating the cervix would be :			
Very useful	Useful	Quite useful	Not useful
20	11	5	1
Visualising the student's progress on the screen would be :			
Very helpful	Helpful	Not helpful	
24	13	0	

Figure 3 shows features used for early pregnancy diagnosis. They were rated, in order of usefulness, as size, softness, membrane slip (palpation of the chorioallantois) and corpus luteum on the same side.

Discussion Group

The nine students highlighted some of the problems they had encountered while examining cows. Initially it was considered difficult to feel structures through faeces and the rectal wall and to relate to the relevant anatomy. The view was expressed that the veterinary surgeon could give only limited guidance when the student is palpating cows and therefore the procedure is in part self-taught. Other detrimental factors included trying to feel through an air filled ballooning rectum, and the size of some cows. Features considered useful in an alternative computer based training environment included receiving feedback from the teacher and having time to explore without any welfare implications. A virtual learning environment, without some of the realism of the cow on farm, may prove more conducive to the acquisition of skills in the early stages of training.

Evaluation

Veterinary Surgeons

A range of the results for the haptic properties of anatomical structures assessed by the nine veterinary surgeons are summarised in Figure 4. The pelvic brim was well represented, most rating the shape, size and feel, as good. It was considered to be a useful landmark as the veterinary surgeon can direct the student either cranially or caudally from this point. The cervix required further development and was changed from a circular to an oval cross section, but it also felt too firm. The uterus was adequately

Figure 3. Frequencies of responses from thirty-seven veterinary surgeons relating to the features used during early pregnancy diagnosis.

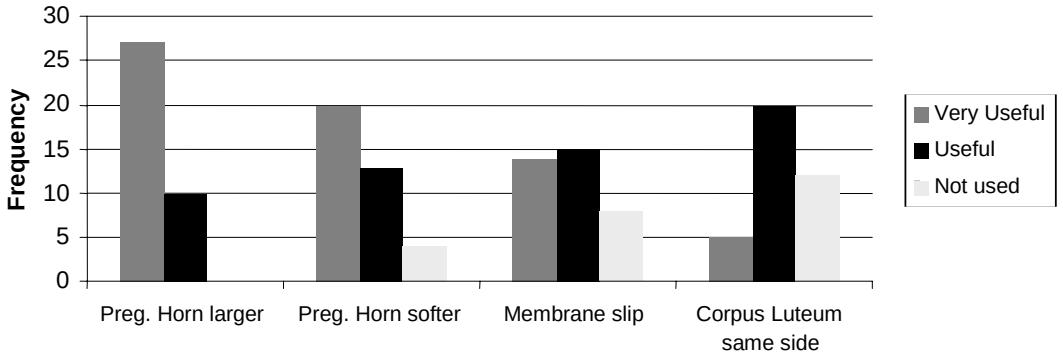
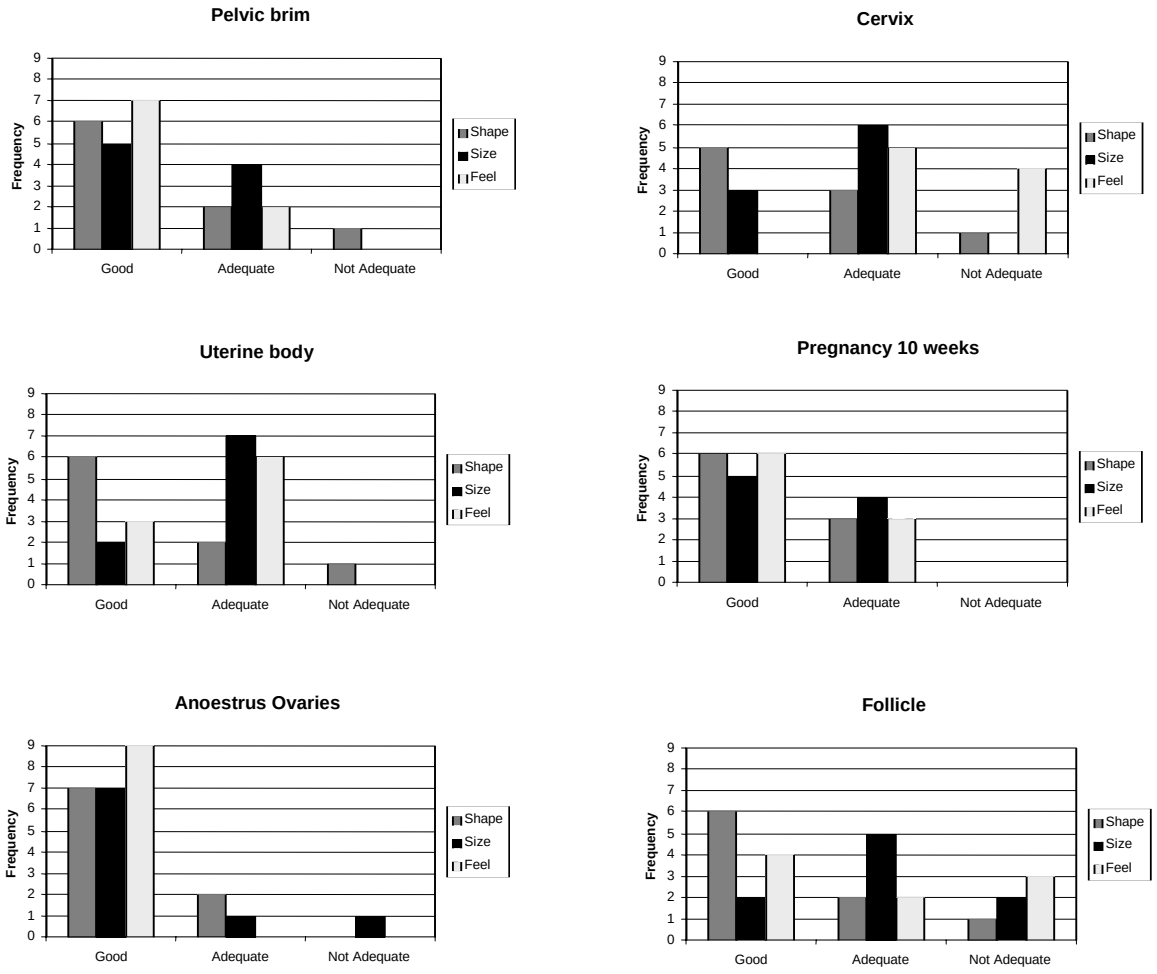


Figure 4. Evaluation results of the haptic properties of simulated anatomical structures assessed by nine veterinary surgeons.



modelled, although the size was closer to that of a heifer than an older cow. The uterine bifurcation was considered to be a particularly important and distinctive landmark for students to recognise. Certain ovarian structures were well represented, the anoestrus ovaries particularly, while the follicle requires further work. The eight and ten-week pregnancies were well rated, although the eight-week pregnancy needed to be slightly larger. It was suggested that pre-clinical students should be taught to examine an example of pregnancy. During EMS students are likely to encounter both non-pregnant and pregnant cows and therefore it would be advantageous to have an appreciation of the differences.

The graphic representation of anatomical structures was considered to be adequate, as this was for a veterinary surgeon, not a student. However, the opinion was expressed that if the whole graphic scene presented to the teacher was tilted it would be easier to see all the pelvic structures and follow the student's progress.

Other comments related to the limitations associated with the PHANToM thimble attachment, a one-finger device. This was considered to be less than ideal, although not as much of a problem as initially expected. Seven out of nine considered using one finger to explore the haptic scene was adequate and five reported perceiving feedback from the whole hand. It was recommended that students were instructed to keep the fingers together and explore the scene with a sweep of the hand, and in the future the system would be modified to support all fingers. Detailed examination of the ovaries and appreciation of membrane slip requires the thumb and fingers, which is not possible with one device.

Interaction with the haptic device through the fibreglass model of the rear half of a cow was thought to improve the realism and enhance the learning environment.

Evaluation

Veterinary Students

The results from the questionnaires completed by the fourteen veterinary students after examining cows following the haptic training are summarised in Table 2. The feedback was quite positive.

Table 2. Haptic training feedback from fourteen veterinary students.

After haptic training your performance			
Greatly improved	Slightly improved	No change	Deteriorated
10	4	0	0
Haptic training before examining real cows would be helpful			
Definitely	Maybe	No	
14	0	0	

DISCUSSION

There are difficulties associated with learning and teaching bovine rectal palpation. A computer based teaching tool was developed to complement methods currently available during the undergraduate curriculum. The bovine rectal palpation simulator allows the teacher to give guidance and the student to develop skills while exploring the virtual pelvic and reproductive scenes. The levels within the programme support the initial learning process of pre-clinical students and enhance the skills of more experienced students. The range of options allows students to experience various scenarios with more flexibility than physical models or real cows.

In the future, experiments are planned to further validate the simulator as a teaching tool, measuring the degree to which skills developed during haptic training are transferable to rectal examination of the cow. It is possible to use more than one PHANToM device simultaneously (Devarajan *et al* 2001) and therefore simulate palpation of the ovary with the thumb and finger. The model will be expanded to include more advanced stages of pregnancy, with representation of fremitus and placentomes, and examples of disease. As well as the bovine version the simulator could be modified to teach other clinical scenarios such as rectal examination for equine colic cases and abdominal palpation of the dog and cat.

Evaluation of the haptic teaching tool with veterinary surgeons and students demonstrated that bovine rectal palpation can be simulated in a virtual environment. The students' feedback suggested that their performance rectalling cows improved as a result of haptic training. Furthermore, there is great potential for haptic teaching tools in veterinary training in the future.

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