A Virtual Reality Simulator for Shoulder Arthroscopy – Face and Construct Validity

Roger J Emery[1], Sofia Bayona[2], Chinmay Gupte[1], Fernando Bello[1]

[1]*Department of Surgery & Cancer, Imperial College London*

[2]*Department of Computer Architecture and Technology, Computing Sciences, and Artificial Intelligence, Universidad Rey Juan Carlos, Madrid*

r.emery@imperial.ac.uk

INTRODUCTION

Virtual Reality surgical simulators offer great possibilities in surgical education. They allow the training of psychomotor skills and are learner centred. Trainees can practice in a non-threatening environment and learn from errors without involving any risk to the patient.

Despite these known advantages, there are challenges to the widespread use of simulators and simulation-based environments. One of them is the need for further research to validate them rigorously [1], so that enough evidence can be provided about their effectiveness and the transfer of skills from the simulated environment to the operating theatre.

This paper presents a study to evaluate a virtual reality simulator for shoulder arthroscopy. Specifically, we address two particular types of validity: face validity (the extent to which the simulator resembles reality), and construct validity (ability to objectively differentiate between subjects with varying levels of arthroscopic experience).

MATERIALS AND METHODS

An experiment with 53 subjects (ranging from inexperienced medical students to consultants) was carried out with the virtual reality arthroscopy simulator *insightArthroVR*® [2] to evaluate its face and construct validity.

Subjects were grouped into ***novices*** (no arthroscopic experience as the main surgeon), ***intermediates*** (less than 50 arthroscopy procedures as the main surgeon), and ***experts*** (50 or more arthroscopy procedures as the main surgeon). Participants had to perform 3 simulated shoulder arthroscopic procedures and then answer a questionnaire.

The arthroscopic simulator consists of a platform composed by two haptic devices that provide force feedback (Sensable PHANTOM Omni [3]). A simulated arthroscope (an optical instrument inserted through a small incision that allows doctors to view the interior of a joint) and the instruments are inserted into a simulated shoulder through the portals. They are handled like in real arthroscopy and a monitor shows the arthroscopic view according to the simulated arthroscope's movements (see Fig 1).

Fig. 1 Virtual reality simulator *insightArthroVR*® Courtesy of GMV.

Each subject performed three simulated procedures (specifically designed for this study) in the following order:

- **Procedure 1:** ***A shoulder diagnostic arthroscopy within the gleno-humeral cavity.*** In this procedure, the arthroscope is inserted through the posterior portal.
- **Procedure 2:** ***A sub-acromial examination.*** In this procedure, the arthroscope is inserted through a lateral portal and the probe through an anterior inferior portal.
- **Procedure 3:** ***A palpation of a posterior Bankart lesion.*** In this procedure, the arthroscope needs to be inserted through an anterior portal whereas the probe is inserted through the posterior portal.

The simulator registered objective metrics:

- ***Completion time:*** the time (in seconds) subjects took in completing the procedure
- ***Camera path***: Length (in mm) of the path covered with the arthroscope
- ***Camera roughness***: Roughness handling the arthroscope
- ***Probe path***: Length of the path covered with the probe
- ***Probe roughness***: Roughness handling the probe.

In order to test the face validity of the simulator, we designed a questionnaire (using a five-point rating Likert-type scale) that gathered information about subjects' previous clinical and arthroscopic experience, and asked about their experience using the simulator, the usefulness of the simulator, and their view on the objective metrics provided by the simulator.

The statistical package SPSS was used for data analysis. After all data was collected, we analysed the subjective opinion on the simulator, and performed non-parametric tests to compare the rank of the means of the metrics that the simulator registered during each exercise for the different expertise groups.

RESULTS

The data collected through the questionnaire shows that the simulator has good face validity. Next we summarize some of the most relevant data:

- 84.9% of the participants agreed (or strongly agreed) that the simulator provides an ***insight into the skills*** required in arthroscopy
- Every subject (100%) agreed or strongly agreed that ***the whole experience with the simulator was enjoyable***.
- 96.2% think (either agree or strongly agree) that the simulator is ***useful for training surgical skills*** (mean 4.42, σ=0.58).
- One participant (1.9%) disagreed with the suggestion that the ***simulator should be an optional tool available to all students who want to use it***.
- 92.4% of the participants think (either agree of strongly agree) that ***the simulator is useful for learning new surgical skills***.
- Nobody disagreed with the statement that ***the objective metrics provided by the simulator are useful***.
- 71.7% agreed that the simulator is ***useful for assessing arthroscopic skills***.

Regarding the simulated procedures and the performance metrics automatically registered, results prove that the simulator was able to distinguish subjects depending on their level of arthroscopic experience. In Fig 2 we can see for ***Procedure 1,*** the values of ***Camera path*** metric (in mm) for the different experience groups.

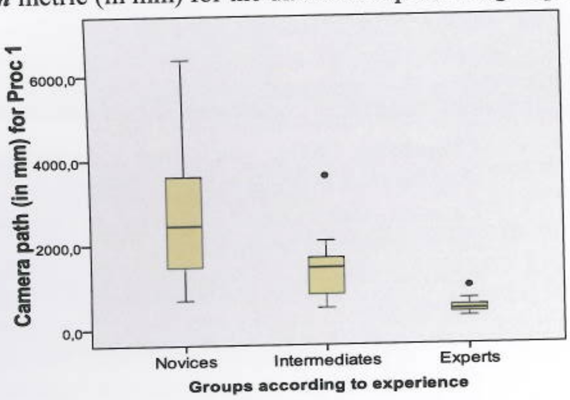

Fig. 2 Values obtained in *Proc 1* for *Camera path* (in mm) for each experience group. We can observe how experts are able to perform the procedure with more economy of movement, covering less distance with the arthroscope.

We performed a Kruskal-Wallis rank mean comparison between the experience groups for each metric and procedure. The detailed analysis for each specific metric and procedure is shown on Table 1.

Table 1 Results for construct validity. The values represent the variance of the ranks in each metric mean among the experience groups (*p-value* is shown in brackets). The asterisk indicates a *p-value* < 0.05, implying significant differences in the metric mean rank according to experience.

Metric	Proc 1	Proc 2	Proc 3
Completion time	23.5 (0.000*)	19.5 (0.000*)	6.7 (0.035*)
Camera path	25.7 (0.000*)	15.2 (0.001*)	3.8 (0.149)
Camera roughness	12.7 (0.002*)	3.2 (0.197)	1.6 (0.440)
Probe path	Not applicable	7.7 (0.022*)	2.6 (0.279)
Probe roughness	Not applicable	3.1 (0.216)	0.6 (0.723)

DISCUSSION

The simulator was considered useful for training surgical skills and, according to the great majority of our participants, it should be an optional tool available to all students who want to use it. Additionally, the objective metrics automatically registered by the simulator were considered useful by the participants, and they considered the simulator as a useful tool for assessing arthroscopic skills.

For the three simulated procedures designed for our study, the simulator was able to distinguish between different levels of experience. The simulator proved construct validity for most of the objective metrics registered (***completion time***, ***camera path***, ***camera roughness***, and ***probe path***). This opens new possibilities about using VR simulators as an additional tool for the assessment of arthroscopic surgeons.

Further research needs to be done to evaluate other types of validity and the learning effect of this VR simulator, and new studies should be carried out to determine if the skills acquired with the simulator are transferable to the operating theatre. Nevertheless, results are promising, and most of our participants already value the simulator as a useful tool for learning, training, and assessing arthroscopic surgical skills.

REFERENCES

[1] Bayona S, Fernández JM, Bayona P, Pastor L. A new assessment methodology for virtual reality surgical simulators. Computer Animation and Virtual Worlds, 2009;20(1):39-52.

[2] GMV Innovating Solutions, 2011. http://www.gmv.com

[3] Sensable Technologies. OpenHaptics toolkit. 2011. www.sensable.com