Using Virtual Reality in Lumbar Puncture Training Improves Students Learning Experience

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Abstract

Background

Lumbar puncture (LP) is a commonly performed medical procedure in a wide range of indications. Virtual reality (VR) provides a stimulating, safe and efficient learning environment. We report the design and the evaluation of a three dimensions (3D) video training for LP procedure.

Methods

We recorded a stereoscopic 180-degrees 3D video from two LPs performed in clinical setting in Fernand Widal Lariboisière University Hospital, Paris, France. Video was administrated to third-year medical students as well as to a residents and attendings group during LP simulation-based training sessions.

Results

On 168 participants (108 novice third-year medical students, and 60 residents and attendings with prior LP experience), satisfaction after video exposure was high (rated 4.7 ± 0.6 on a 5-point scale). No significant discomfort was reported (comfort score graded 4.5 ± 0.8 on 5). LP-naïve students displayed higher satisfaction and perceived benefit than participants with prior LP experience (overall, $P < 0.05$). Trainees evaluated favorably the 3D feature and supported the development of similar supports for other medical procedures (respectively, 3.9 ± 1.1 and 4.4 ± 0.9 on 5).

Conclusion

We report our experience with a 3D video for LP training. VR support could increase knowledge retention and skills acquisition in association to LP simulation training.

Background

Lumbar puncture (LP) is an important diagnostic and therapeutic procedure performed in various clinical setting (Wright et al. 2012; Costerus et al. 2018; Shaw et al. 2018). LP is classically performed with the palpation method, where the operator palpates the anatomic landmarks around lumbar spines to identify the needle insertion site (usually L3/L4 or L4/L5 intervertebral disc spaces). This can be challenging in certain patients (*e.g.*, overweight, pregnant patients, back deformation, prior spine surgery) and can potentially cause side effects fostered by suboptimal practice (Paquet et al. 2012; Duits et al. 2016; Engelborghs et al. 2017). Until recently, training usually involved the learning model of "see one, do one, teach one" where a trainee's first LP attempt occurs in real life in a high-stakes environment. Simulation technology using models has shown efficiency in improving teaching and operator experiences in technical gestures and has been developed in LP (Barsuk et al. 2012; Lydon et al. 2019; Akaishi et al. 2020; Gaubert et al. 2021). It was reported to improve students theoretical knowledge and confidence level in performing LP and improved the success rate and the autonomy of the students (Henriksen et al.

2018; Gaubert et al. 2021). However, while simulation is becoming central to healthcare education, it requires significantly more resources than traditional education.

Virtual reality (VR) is emerging as a new method of delivering simulation (Pottle 2019; Zhao et al. 2020; Sattler et al. 2020; Mansoor et al. 2021). VR requires the use of hardware (virtual reality headset) to create an immersive simulated environment. It allows for the exploration of a real or artificial 3D environment in real-time, using 180- or 360- degrees videos. The participant becomes completely immersed in an interactive virtual environment and is provided with first-person active learning experience (Hu Au and Lee 2017; Bailenson 2018). Nevertheless, there is a limited evidence of knowledge on the educational use of the technology, compared to other teaching techniques (Zulkiewicz et al. 2020; Arents et al. 2021).

We report the design and development of a prototype stereoscopic 180-degrees video of LP in clinical setting and its evaluation in a pilot cohort.

Methods

Participants

The study was conducted in Université de Paris, Paris, France, from October 2020 to June 2021. We systematically included participants, during five LP simulation-based training sessions. First sessions included residents and attendings, who had already performed LP in real clinical setting at the time of training. The 2nd series of sessions included 3rd year medical students undergoing LP training session in their regular *curriculum*, with no prior LP experience. Each participant was provided a detailed overview of the study and informed consent was obtained.

Development of the video

Two LPs performed in clinical setting in the Cognitive Neurology Centre, Lariboisière Fernand Widal Hospital, using atraumatic needle (pencil-point needle) were recorded (Fig. 1). Patients filmed for the video purpose underwent LP in the context of diagnosis work-up for neurological symptoms. Procedures recorded included all the steps of LP procedure: installation of the patients, disinfection steps and sterile conditions setting, placement of the needle, collection of the liquid and end of the procedure. The camera angle gurney attempted to capture the operator view. The video was first recorded in 360-degrees, but the backward view was evaluated as of moderate interest. The video was secondarily recorded in 180-degrees allowing for a stereoscopic video (with distinct right and left eye view): two objectives facing in the same direction each recorded a 180-degrees half sphere image, one for each eye. The camera model used was Insta360 EVO (Arashi Vision Inc, China). The camera was disposed on a swivel arm for optimal filming (Manfrotto, Italy).

Software used for video treatment were: Insta 360 Studio 2019, Insta360 PR plug-in for Première Pro, Adobe Première Pro 2019 et 2020 for editing and Adobe Medias Encoder 2019 et 2020 for encoding and

export. No stitching of the images was needed. Caption with explanation on each step of the procedure were added with the text placed in the operator view at 0 degree (**Appendices, Video Script**).

The final video lasted 5 minutes after edition and was administrated through Gizmo VR Video Player, Gizmolite®, Cyprus (Fig. 2). The VR headset used was Oculus Go (Oculus, Microsoft, USA). The video is available on the YouTube platform at the following URL: <https://youtu.be/EqtrQUfKO9U>.

Administration of the video

The video was administrated to included subjects during a live 2-hours simulation-based training session. Simulation training protocol was previously published (Gaubert et al. 2021). In brief, the course consisted of a rapid evidence-based presentation, reviewing anatomy, indications, complications, and techniques for performing LPs in a regular video format. It was followed by LP demonstration and hands-on practice of LPs on simulators with direct feed-back by instructors. The video was uploaded on YouTube to allow for repeated viewing, with the option of watching it as a standard video or a 180-degree VR video.

Evaluation methods

We performed a survey to evaluate comfort during viewing and satisfaction after administration of the video (**Appendices, Survey**). Participants were given a questionnaire directly after the LP training session, to assess comfort during viewing, occurrence of any adverse symptoms and perceived benefit and interest of the video. Participant were finally asked to grade their overall satisfaction. Users were also encouraged to provide verbal constructive feed-back.

Statistical analysis

Analysis was performed using GraphPad Prism version 9.00 (GraphPad Software, California USA). Data were described as mean and standard deviation or as number of subjects and percentage. Differences between medical students group and attendings & residents group were studied using Mann-Whiney test for continuous variables and Chi-2 test for categorical variables. A p-value < 0.05 was considered significant.

Data Availability

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Results

One-hundred sixty-eight subjects were administrated the video and completed the survey during five simulation training sessions carried out at Université de Paris, on October 26 and 27, 2020 and June the 8, 9 and 11, 2021 (Table 1). The first group of enrolled subjects consisted of 108 third-year medical students. Forty-four percent of participants had already experienced a 360-degrees video in VR. Thirteen

percent possessed a personal VR headset. Sixty subjects, including residents and attendings with prior LP experience were also included.

Table 1
, Trainees characteristics

n = 168	Medical students (n = 108)	Attendings and residents (n = 60)
Age, years	21.5 (1.7)	27.8 (4.0)
Men, n (%)	28% (30)	40% (24)
Prior exposure to VR, n (%)	44% (48)	40% (24)
Possession of VR headset, n (%)	13 % (14)	7% (4)
Data is presented as mean ± SD or number of subjects (%). Abbreviations: LP, lumbar puncture; SD, standard deviation; VR, virtual reality.		

Video could be administrated to 20 subjects by training session of 2 hours, using two VR headsets and one dedicated technical engineer. Sanitization of the device and of the administration area was performed between each and every participant.

Comfort of viewing and cybersickness

Comfort score during video exposure was overall high, rated 4.5 ± 0.8 on 5 (Table 2). Scores of dizziness, headache and eye discomfort remained low (respectively: 0.5 ± 0.9 , 0.4 ± 0.7 and 0.3 ± 0.7). Cybersickness was experienced by 5 percent of subjects.

Table 2
, Evaluation of the video

Confort				
	All subjects (n = 168)			
Global comfort score (rated 0 to 5)	4.5 (0.8)			
Dizziness (rated 0 to 5)	0.5 (0.9)			
Nausea (% , n of subjects)	5% (9)			
Headaches (rated 0 to 5)	0.4 (0.7)			
Eye pain (rated 0 to 5)	0.3 (0.7)			
Satisfaction				
	All subjects (n = 168)	Medical students (n = 108)	Residents and attendings (n = 60)	p-value [#]
Satisfaction level (rated 0 to 5)	4.7 (0.6)	4.8 (0.5)	4.5 (0.7)	0.0037
Rated interest of VR in addition to simulation (rated 0 to 5)	4.1 (1.0)	4.2 (0.9)	3.9 (0.9)	0.0338
Rated interest of VR to 2D video (rated 0 to 5)	3.9 (1.1)	4.0 (1.0)	3.7 (1.2)	0.0733
Rated interest of extension of VR for other procedures (rated 0 to 5)	4.4 (0.9)	4.5 (0.9)	4.4 (0.9)	0.4956
Interested in having the video in open-access, % (n)	73% (122)	84 % (91)	55% (33)	< 0.0001
Data is presented as mean ± SD or number of subjects (%).All parameters were assessed on a 5-points scale (0, no interest, utility or satisfaction to 5, high interest, utility or satisfaction).				
# LP-naïve medical students versus attending and residents group with prior LP experience, using Mann-Whitney test. P-value < 0.05 is considered significant.				
Abbreviations: LP, lumbar puncture; SD, standard deviation; VR: virtual reality				

Evaluation and interest of the training

The overall level of satisfaction of the included subjects was high: 4.7 ± 0.6 rated on a 5-point scale (Table 2). Satisfaction was higher in the medical student group than in the subjects with prior LP experience (4.8 ± 0.5 versus 4.5 ± 0.7 , $P = 0.0037$).

The interest of the video in complement of simulation training was perceived positively in the overall cohort (4.1 ± 1.0 on a 5-points scale). The perceived interest was higher in the medical student group (4.2 ± 0.9) compared to the attendings and residents group (3.9 ± 0.9 , $P = 0.0338$). The added value of the 3D 180-degrees characteristic of video compared to a 2D video was quoted to 3.9 ± 1.1 on a 5-points scale and did not differ between groups. Participants believed that the extension of VR to other medical procedure would be of high interest with a mean score of 4.4 ± 0.9 , with no difference between groups. In addition, 73 % of total participants were interested in being able to have the video in open access for repeated viewing. This interest was higher in the medical student group (84% versus 55%, $P < 0.0001$).

Discussion

In this study, we report the development of a 180-degrees stereoscopic LP video in clinical setting. The evaluation of this video in a pilot study on 168 subjects, including 108 LP naive- trainees, showed a good tolerance and feasibility and high satisfaction among the students. Third-year medical students rated higher the perceived benefits and interests of the experience than subjects with prior LP experience, suggesting a real added-value of the video. Overall, it was found that implementing 180-degrees VR video into LP training could provide a beneficial learning experience.

Previous studies have highlighted the promise of VR video in medical education (Hu Au and Lee 2017; Taubert et al. 2019; Pottle 2019; Lohre et al. 2020). Interactive media and online materials provide engaging experience and can help in conceptualizing intricate 3D data (in surgery or anatomy) or integrating the sequences of medical technical procedures (Zhao et al. 2020; Sattler et al. 2020; Chan et al. 2021). In a survey by Sultan *et al*, 93 % of 169 undergraduate medical students were willing to engage in VR support for medical education (Sultan et al. 2019). Moreover, knowledge retention and skills acquisition scores were higher regarding after a 360-degrees video training compared to a classical lecture in a basic sciences module session. A meta-analysis on 21 studies reported higher accuracy in medical practice by people trained through VR for laparoscopic surgery training in 87% of cases compared to conventional training (Samadbeik et al. 2018).

LP is an essential tool in daily clinical practice and despite being a relatively safe procedure performed at patient bedside, a negative attitude appears to persist both in general population and in medical students (Duits et al. 2016; Tsvetkova et al. 2017). In several studies, medical trainees associated LP with a high level of difficulty and a low level of confidence compared to other similar bedside procedures (Dehmer et al. 2013; von Cranach et al. 2019). The development of simulation based training has allowed practice in a safe environment and significantly increased confidence and real life procedural skills (Barsuk et al. 2012; Gaubert et al. 2021).

Our aim was to develop a 180-degree video that would constitute an educational precursor to simulation session. Preliminary feedback received on this new teaching tool was positive. Our preliminary assessment showed that overall satisfaction score was high. Cybersickness characterized by blurred vision, nausea or headache was seldom experienced by our participants. The video was evaluated an

interesting enhancement to the simulation training. Interestingly, the medical students groups had a significantly higher satisfaction, perceived a higher interest in the video and were keener to have the video in open access for repeated use than the group of attendings and residents with prior LP experience. This suggests that the video provided them with additional content, probably on real-life setting conditions (patient and operator installation during the gesture, communication with the patient during the procedure) that was not given by the simulation-training and that was not perceived by subjects that had already performed LP. The 3D characteristic of the video was seen as an addition of more moderate interest compared to conventional 2-dimension video. It is known that the perceived interest of 3D increases with the interaction level, lower in a passive video, which could account for this lower rating (Pottle 2019). All in all, the association of LP training session on simulators allowing for technical skills learning and the 3D-video providing education about patients installation and full conduct of the procedure in "real life" could be an optimal teaching method.

VR 180- or 360-degrees video present with several advantages. On a technical level, the material requirement is low: a connected screen device (VR headset, computer or mobile device) on which the video has been charged is the only required material. Each group can perform the activity in any environment being provided the VR headset. A large number of trainees can use this tool simultaneously and its viewing can be repeated as needed. There is no need for continuous supervision. On a practical level, it was easy to produce, compared to immersive VR where the production is time consuming and often requires a large production team. The video could be recorded and edited within a few days. The low cost is also a significant aspect, when considering applying it into education especially for low-income settings. Finally, the video modality allows for remote teaching, which is very valuable in the current Covid pandemic context and the associated need to restrict physical contact (Sandrone et al. 2021).

We made the choice of a VR 180-degrees video(Stefaniak 2020). Evolving in a 180-degrees space, viewers focus could be guided in a stereoscopic first-person point-of-view. The video did not provide full-immersion as in 360-degrees or the ability to look in any direction, but in our cases, it was not needed as the patient's back and the hands of the operator were the points of interest. The 180-degrees format also eliminated resolution and bandwidth issue that can be observed with 360-VR video format.

Our study has several limitations. VR is a relatively new pedagogical technique, so there is no high-quality evidence on the effectiveness of VR- based teaching. Evaluation of the effect of the video training on the performance of LP for the first time on a patient will be the next step of assessment, as it was done for evaluation of simulation training(Gaubert et al. 2021). A better perception of benefit could also be achieved by involving students from several academic levels. Recording different clinical situations (LP procedure on an obese subject or in lateral decubitus) would also allow students to confront themselves to the different situations a physician can encounter in clinical practice (Edwards et al. 2015). Nevertheless, we think our results open a door for future studies to further investigate the development of a VR-based LP training system by demonstrating the feasibility of the administration of the video and encouraging data regarding student's interest.

Conclusions

We could develop an innovative VR 180-degrees video for LP training. We provide to the community a sample of lumbar puncture VR video that can be freely used for future teaching. In a pilot cohort, the video could be efficiently implemented and its perceived interest and added value to the simulation training was evaluated as high by medical students. A future study will be needed to confirm that our VR video adds value to already established LP simulation training and establish whether it is a valuable tool to improve student learning and LP performance in real-life.

Abbreviations

3D, three-dimensions, LP, lumbar puncture, VR, virtual reality, SD, standard deviation

Declarations

Ethics approval and consent to participate

This project has received approval from the local Ethic committee University Hospital Lariboisière Fernand Widal (CE). The study conforms with World Medical Association Declaration of Helsinki.

Patients filmed for the video gave written and oral consents to diffuse the video to students and for academic publication. Faces were blurred during video processing to prevent identification. Students participating in the study gave consent and additional consent was obtained for the picture displaying the video administration.

Consent for publication

Patients filmed gave written and oral consents to diffuse the video to students and for academic publication.

Availability of data and materials

Data is available from the corresponding author upon reasonable request.

Competing interests

The authors do not report any disclosure regarding this work.

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Authors' contributions

JD and CP have designed the study, written the protocol and submitted ethics. LGM, PFC, PP and ED have allowed for technical platform access, designed and engineered the 180-degrees video and organised VR headset deployment. CP, JD, AV and LGM have performed the administration and evaluation of the video. AV, LGM, PFC, PP, ED, CP and JD have analysed the data and written the article. All authors have read and approved the manuscript.

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References

1. Akaishi Y, Okada Y, Lee-Jayaram J, Seo JS, Yamada T, Berg BW. 2020. Validity evidence of a task trainer for normal and difficult lumbar puncture: A cross-sectional study. *Medicine (Baltimore)*. 99(41):e22622. <https://doi.org/10.1097/MD.00000000000022622>
2. Arents V, de Groot PCM, Struben VMD, van Stralen KJ. 2021. Use of 360° virtual reality video in medical obstetrical education: a quasi-experimental design. *BMC Med Educ*. 21(1):202. <https://doi.org/10.1186/s12909-021-02628-5>
3. Bailenson J. 2018. *Experience on Demand: What Virtual Reality Is, How It Works, and What It Can Do*. [place unknown]: W. W. Norton & Company.
4. Barsuk JH, Cohen ER, Caprio T, McGaghie WC, Simuni T, Wayne DB. 2012. Simulation-based education with mastery learning improves residents' lumbar puncture skills. *Neurology*. 79(2):132–137. <https://doi.org/10.1212/WNL.0b013e31825dd39d>
5. Chan V, Larson ND, Moody DA, Moyer DG, Shah NL. 2021. Impact of 360° vs 2D Videos on Engagement in Anatomy Education. *Cureus*. 13(4):e14260. <https://doi.org/10.7759/cureus.14260>
6. Costerus JM, Brouwer MC, van de Beek D. 2018. Technological advances and changing indications for lumbar puncture in neurological disorders. *Lancet Neurol*. 17(3):268–278. [https://doi.org/10.1016/S1474-4422\(18\)30033-4](https://doi.org/10.1016/S1474-4422(18)30033-4)
7. von Cranach M, Backhaus T, Brich J. 2019. Medical students' attitudes toward lumbar puncture-And how to change. *Brain Behav*. 9(6):e01310. <https://doi.org/10.1002/brb3.1310>
8. Dehmer JJ, Amos KD, Farrell TM, Meyer AA, Newton WP, Meyers MO. 2013. Competence and confidence with basic procedural skills: the experience and opinions of fourth-year medical students at a single institution. *Acad Med*. 88(5):682–687. <https://doi.org/10.1097/ACM.0b013e31828b0007>
9. Duits FH, Martinez-Lage P, Paquet C, Engelborghs S, Lleó A, Hausner L, Molinuevo JL, Stomrud E, Farotti L, Ramakers IHGB, et al. 2016. Performance and complications of lumbar puncture in memory clinics: Results of the multicenter lumbar puncture feasibility study. *Alzheimers Dement*. 12(2):154–163. <https://doi.org/10.1016/j.jalz.2015.08.003>

10. Edwards C, Leira EC, Gonzalez-Alegre P. 2015. Residency training: a failed lumbar puncture is more about obesity than lack of ability. *Neurology*. 84(10):e69-72.
<https://doi.org/10.1212/WNL.0000000000001335>
11. Engelborghs S, Niemantsverdriet E, Struyfs H, Blennow K, Brouns R, Comabella M, Dujmovic I, van der Flier W, Frölich L, Galimberti D, et al. 2017. Consensus guidelines for lumbar puncture in patients with neurological diseases. *Alzheimers Dement (Amst)*. 8:111–126.
<https://doi.org/10.1016/j.dadm.2017.04.007>
12. Gaubert S, Blet A, Dib F, Ceccaldi P-F, Brock T, Calixte M, De Macédo L, Dujardin T, Jean-Louis L, Leghima D, et al. 2021. Positive effects of lumbar puncture simulation training for medical students in clinical practice. *BMC Med Educ*. 21(1):18. <https://doi.org/10.1186/s12909-020-02452-3>
13. Henriksen MJV, Wienecke T, Kristiansen J, Park YS, Ringsted C, Konge L. 2018. Opinion and Special Articles: Stress when performing the first lumbar puncture may compromise patient safety. *Neurology*. 90(21):981–987. <https://doi.org/10.1212/WNL.0000000000005556>
14. Hu Au E, Lee JJ. 2017. Virtual reality in education: a tool for learning in the experience age. *IJIE*. 4(4):215. <https://doi.org/10.1504/IJIE.2017.10012691>
15. Lohre R, Wang JC, Lewandrowski K-U, Goel DP. 2020. Virtual reality in spinal endoscopy: a paradigm shift in education to support spine surgeons. *J Spine Surg*. 6(Suppl 1):S208–S223.
<https://doi.org/10.21037/jss.2019.11.16>
16. Lydon S, Reid McDermott B, Ryan E, O'Connor P, Dempsey S, Walsh C, Byrne D. 2019. Can simulation-based education and precision teaching improve paediatric trainees' behavioural fluency in performing lumbar puncture? A pilot study. *BMC Med Educ [Internet]*. [accessed 2021 Mar 30] 19.
<https://doi.org/10.1186/s12909-019-1553-7>
17. Mansoor MS, Khazaei MR, Azizi SM, Niromand E. 2021. Comparison of the effectiveness of lecture instruction and virtual reality-based serious gaming instruction on the medical students' learning outcome about approach to coma. *BMC Med Educ*. 21(1):347. <https://doi.org/10.1186/s12909-021-02771-z>
18. Paquet C, Latour F, Saulnier I, Hanon O. 2012. [Multicenter study on lumbar puncture indication, clinical practice and feasibility]. *Rev Neurol (Paris)*. 168(1):28–32.
<https://doi.org/10.1016/j.neurol.2011.08.012>
19. Pottle J. 2019. Virtual reality and the transformation of medical education. *Future Healthc J*. 6(3):181–185. <https://doi.org/10.7861/fhj.2019-0036>
20. Samadbeik M, Yaaghobi D, Bastani P, Abhari S, Rezaee R, Garavand A. 2018. The Applications of Virtual Reality Technology in Medical Groups Teaching. *J Adv Med Educ Prof*. 6(3):123–129.
21. Sandrone S, Albert DVF, Dunham SR, Kraker J, Noviawaty I, Palm M, Kushlaf H. 2021. Training in Neurology: How Lessons Learned on Teaching, Well-being, and Telemedicine During the COVID-19 Pandemic Can Shape the Future of Neurology Education. *Neurology*. 96(24):e3007–e3010.
<https://doi.org/10.1212/WNL.00000000000012010>

22. Sattler LA, Schuety C, Nau M, Foster DV, Hunninghake J, Sjulín T, Boster J. 2020. Simulation-Based Medical Education Improves Procedural Confidence in Core Invasive Procedures for Military Internal Medicine Residents. *Cureus*. 12(12):e11998. <https://doi.org/10.7759/cureus.11998>
23. Shaw LM, Arias J, Blennow K, Galasko D, Molinuevo JL, Salloway S, Schindler S, Carrillo MC, Hendrix JA, Ross A, et al. 2018. Appropriate use criteria for lumbar puncture and cerebrospinal fluid testing in the diagnosis of Alzheimer's disease. *Alzheimers Dement*. 14(11):1505–1521. <https://doi.org/10.1016/j.jalz.2018.07.220>
24. Stefaniak J, editor. 2020. Cases on Instructional Design and Performance Outcomes in Medical Education: [Internet]. [place unknown]: IGI Global, [accessed 2021 Apr 5]. <https://doi.org/10.4018/978-1-7998-5092-2>
25. Sultan L, Abuznadah W, Al-Jifree H, Khan MA, Alsaywid B, Ashour F. 2019. An Experimental Study On Usefulness Of Virtual Reality 360° In Undergraduate Medical Education. *Adv Med Educ Pract*. 10:907–916. <https://doi.org/10.2147/AMEPS219344>
26. Taubert M, Webber L, Hamilton T, Carr M, Harvey M. 2019. Virtual reality videos used in undergraduate palliative and oncology medical teaching: results of a pilot study. *BMJ Support Palliat Care*. 9(3):281–285. <https://doi.org/10.1136/bmjspcare-2018-001720>
27. Tsvetkova DZ, Bergquist SH, Parker MW, Jarrett TL, Howell JC, Watts KD, Kollhoff A, Roberts DL, Hu WT. 2017. Fear and Uncertainty Do Not Influence Reported Willingness to Undergo Lumbar Punctures in a U.S. Multi-Cultural Cohort. *Front Aging Neurosci*. 9:22. <https://doi.org/10.3389/fnagi.2017.00022>
28. Wright BLC, Lai JTF, Sinclair AJ. 2012. Cerebrospinal fluid and lumbar puncture: a practical review. *J Neurol*. 259(8):1530–1545. <https://doi.org/10.1007/s00415-012-6413-x>
29. Zhao J, Xu X, Jiang H, Ding Y. 2020. The effectiveness of virtual reality-based technology on anatomy teaching: a meta-analysis of randomized controlled studies. *BMC Med Educ*. 20(1):127. <https://doi.org/10.1186/s12909-020-1994-z>
30. Zulkiewicz BA, Boudewyns V, Gupta C, Kirschenbaum A, Lewis MA. 2020. Using 360-Degree Video as a Research Stimulus in Digital Health Studies: Lessons Learned. *JMIR Serious Games*. 8(1):e15422. <https://doi.org/10.2196/15422>

Figures

Figure 1

Figure 1

Acquisition of the video. A. Lateral view of video acquisition. B. Operator view of video acquisition.

Figure 2

Figure 2

Administration to students of the VR video. A. Sample of the stereotaxic view of the video. B. 2 students watching the video with Oculus Go VR headset.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

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