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“Take-home” box trainers are an effective alternative to virtual reality simulators

Marina Yiasemidou, Jonathan De Siqueira, James Tomlinson, Daniel Glassman, Simon Stock, Michael Gough

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Title: "Take-home" box trainers are an effective alternative to virtual reality simulators

Short title: Take home versus virtual reality simulators

Authors: Marina Yiasemidou (1,2), Jonathan De Siqueira (1), James Tomlinson (1), Daniel Glassman (1), Simon Stock (3), Michael Gough (1)

1. School of Surgery, Health Education Yorkshire and the Humber, Leeds, UK
2. Leeds Institute of Biomedical and Clinical Sciences, University of Leeds, Leeds, UK
3. World Mate Emergency Hospital, Battambang, Cambodia

Corresponding author:

Marina Yiasemidou, MBBS, MSc, MRCS (Eng), PGCer

7.26 Clinical Science Building, St. James University Hospital,

Beckett street, LS7 9TF, Leeds, West Yorkshire, UK

Email: M.Yiasemidou@leeds.ac.uk

Tel: +44 [0] 7975531067

Compliance with ethical standards

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Conflict of interest: All authors declare no conflict of interests.

Author contributions:

Marina Yiasemidou: Co-design of the study, data collection, data analysis and write up

Jonathan De Siqueira: Co-design of the study

Daniel Glassman: Recruitment, data collection and data analysis

James Tomlinson: Recruitment and data collection

Michael Gough: Overall supervision of project including write up of manuscript.

Abstract

Background: Practice on Virtual Reality simulators (VRS) have been shown to improve surgical performance. However, VRS are expensive and usually housed in surgical skills centres that may be inaccessible at times convenient for surgical trainees to practice. Conversely, box trainers are inexpensive and can be used anywhere at anytime. This study assesses “take-home” Box Trainers (BT) as an alternative to VRS.

Methods: After baseline assessments (two simulated laparoscopic cholecystectomies, one on a VRS and one on a BT) 25 surgical trainees were randomised to two groups. Trainees were asked to practice 3 basic laparoscopic tasks for 6 weeks (BT group using a “take-home” box trainer; VR group using VRS in clinical skills centres). After the practice period all performed two LC, one on a VRS and one on a BT; (i.e. post-training assessment). VRS provided metrics (total time (TT), number of movements (NOM) instrument tip path length (PL)) and expert video assessment of cholecystectomy in a BT (GOALS score) were recorded. Performance during pre- and post-training assessment was compared.

Results: The BT group showed a significant improvement for all VRS metrics (p=0.008) and the efficiency category of GOALS score (p=0.03). Only TT improved in the VRS group and none of the GOALS categories demonstrated a statistically significant improvement after training.

Finally, the improvement in VRS metrics in the BT group was significantly greater than in the VR group (TT p=0.005, NOM p=0.042, PL p=0.031) although there were no differences in the GOALS scores between the groups.

Conclusion: This study suggests that a basic “take-home” BTs is a suitable alternative to VRSs.

Introduction

Compared to open surgery laparoscopic procedures require enhanced hand-eye coordination, the ability to operate while receiving a 2D visual image and the capacity to adjust to the “fulcrum effect” (small movements outside the abdomen are translated into larger ones within the abdomen) [1]. Several training models have been proposed for teaching laparoscopic skills including box trainers and virtual reality simulators [2].

Virtual reality simulators have been shown to improve surgical skills for a variety of different operations [2-6] and could potentially be used for assessing surgical competency [7]. However, they are relatively immobile, expensive [8,9] and are usually located in simulation skills centres that may not be accessible to trainees at the times when they can use them [10]. Further, they require dedicated staff and facilities [11,12]. Conversely, box trainers are mobile and can be used in any place at any time. They are also considered to be more cost-effective [13]. Box trainers have also been shown to improve surgical performance in a variety of scenarios [14] and provide the option of practicing on animal tissue which some believe increases the realism of the simulated procedure, particularly in respect to haptics [15]. Finally, Munz et al. have shown that box trainers and VRS used during supervised practice provide a similar benefit [2].

The current study compares the efficacy of unsupervised training (other than induction) on VR simulators located in clinical skills centres and “take-home” box trainers on the subsequent performance of cholecystectomy

Methods

Twenty-five core surgical trainees and early years specialist registrars (ST3 & 4) who had performed fewer than 15 laparoscopic cholecystectomies as primary surgeon, were randomised to two groups (Groups VR & BT). All participants underwent baseline assessments. These included a simulated laparoscopic cholecystectomy using a physical model (fig. 1) placed in a box trainer (fig. 2) and one on a VR simulator (LAP Mentor^{TM}, Simbionix) (fig. 1). Group BT was then given a box trainer (Inovus Surgical Solutions ©, St. Helens, UK) to take home and asked to practice 3 basic tasks (peg transfer, precision cutting and clip application) as often as they could over the next 6 weeks. A minimum of 25 repetitions was recommended. Group VR were asked to do the same using VR simulators housed in regional clinical skills centres. After six weeks practice a second assessment of trainee performance was made using the same testing mechanisms as at baseline (i.e. one laparoscopic cholecystectomy on a BT and one on a VRS).

Evaluation of cholecystectomy performed on VR simulator

The simulator at the end of each procedure provided several metrics. In this study the following three used for assessing surgical performance: (i) number of instrumental tip movements – NOM, (ii) Path length of instrument tip – PL and (iii) total time taken to extract the gall bladder from the liver bed – TT. These metrics have been shown to reflect surgical proficiency [16].

Evaluation of cholecystectomy performed on box trainer

These procedures were recorded on video and were later assessed by two blinded experts. A validated scoring scheme, Global Operative Assessment of Laparoscopic Skills (GOALS) [17], was used for this purpose. The “autonomy” category of GOALS was not included within the scoring results as for purposes of maintaining the same experimental conditions for all candidates, trainees were not allowed to ask for guidance on how to complete the procedure.

Data analysis and statistics

Baseline performance (GOALS [mean of scores by 2 experts] and VR metrics) was compared to the “post-training” data in both groups with trainees acting as their own controls. A paired t-test was used to compare continuous metrics (PL) whilst the Wilcoxon test was employed for discrete data (TT, NOM). A Mann-Whitney test for used for all other comparisons, including the number of repetitions (recorded in diary) performed by each trainee/group.

Intra rater variance for the GOALS scores was assessed using the Intraclass Coefficient (ICC).

All statistics were performed on SPSS® v22 (IBM, New York, US).

Results:

Sixteen of 25 recruited trainees (9:BT; 7: VR) completed the study. Six dropped-out of the study and 3 were excluded as they had exceeded the threshold of 15 laparoscopic cholecystectomies as primary surgeon during the 6 weeks training period.

Comparison of baseline and post-practice performance:

VR simulator assessment:

Trainees in the BT group performed significantly better after practice compared to their baseline performance metrics when performing a VR cholecystectomy (TT p=0.008, NOM p=0.008, PL p=0.008) Conversely, trainees in the VR group only improved in respect of the time taken to complete the procedure (TT: p=0.018; NOM: p=0.063; PL: p=0.128). These data are summarised in table 1 and figure 1.

Box trainer assessment:

With respect to the GOALS scores (table 3) trainees in the BT group performed cholecystectomy more efficiently after practice compared to baseline (p= 0.027). In contrast, the performance of the VR group did not differ from baseline for any of the parameters assessed.

Comparison of BT and VR group improvement in performing a Laparoscopic Cholecystectomy (LC) on a VR simulator:

Improvement in simulation metrics and GOALS score from baseline to post-practice assessment were compared between the two groups.

VR simulator assessment:

The BT group showed a significantly greater improvement than the VR group for all VR metrics (BT v VR: TT p=0.005, NOM p=0.042, PL p=0.031). This data are presented in table 2.

Box trainer assessment:

There were no differences in the improvement of GOALS scores for the BT group compared to the VR group (table 4).

Inter-rater correlation:

The ICC between the two blinded assessors evaluating the baseline and post training simulated laparoscopic cholecystectomy on a synthetic model placed in a box trainer was 0.894 (95% C.I 0.849-0.925).

Comparison of number of times tasks were practiced between two groups:

The trainees in the BT group practiced significantly more often than trainees in the VR group (BT: median 20 (iqr: 20- 25); VR: median 10 (iqr: 2-10), p = 0.008).

Discussion

This is a prospective, single-blinded, randomised trial. To the authors' knowledge this is the first randomised controlled trial comparing "take-home" box trainers and high fidelity VR simulators located in clinical skills centres (i.e. current practice). The results of this study show equivalence or even superiority of “take-home” box trainers compared to virtual reality simulators.

The study also indicates that practicing basic laparoscopic skills (i.e. peg transfer, precision cutting and clipping) has a positive impact on subsequent surgical performance of a full procedure, as both the BT and VR group improved their performance at the end of the study, albeit to differing degrees. This may have implications on the cost of training, as a physical (single use) or virtual model of the relevant surgical anatomy may not be necessary in order to train novices to perform full procedures. A box trainer or a desktop virtual simulator, which contains basic laparoscopic skills may suffice to augment performance of laparoscopic procedures.

Despite the existence of the perception that supervised, consultant-led training is of the outmost importance [18], the current study indicates that unsupervised training may also be adequate for enhancing surgical skills. In addition, six weeks appear to produce an improvement in performance, which can assist to formulate the methodology for future studies.

The results of the current study are consistent with studies assessing the didactic effect of supervised practice on box trainers or virtual reality simulators. Several studies showed that virtual reality simulators when compared to no supplementary training improve surgical performance [5,3,19,20]. The VR group in the current study demonstrated improvement in surgical performance after practicing on a virtual reality simulator in regards to time taken to perform the simulated procedure. Similarly training using box trainers was shown to improve surgical skills [21,22] which is in accordance to the BT group demonstrating enhanced surgical performance between baseline and post-training assessment.

Some authors have demonstrated that box trainers are an effective alternative to virtual reality simulators, demonstrating that they have equal or better didactic effect when compared to virtual reality simulators [23-26]. Amongst other arguments, it has also been suggested that haptic feedback in VRS may not be as realistic as the one provided by box trainers [27]. Lifelike haptic feedback provided on the box trainer could be attributing to the results of this study.

Another potential contributing factor to the results of the study is the significantly higher number of practice times observed in the BT group. Increased practice using “take-home” BTs may be due to the on-demand accessibility of BT, which is possible with the use of BTs due to their portability. Conversely, in our region VR simulators, as is often the case in other areas as well, are stored in clinical skills centres which in their vast majority are located in big teaching hospitals and are – all but one - accessible during working hours (e.g. 9am to 5pm).

Reports in the current literature indicate that access to clinical skills centres may be limited [28-30]. Although we have not collected data on the time of day the simulators were used, we speculate that having a box trainer in the convenience of one’s home instead of in a clinical skills centre may have contributed to the increased utilization of the box trainers. Furthermore, the cost of virtual reality simulators makes the acquisition of such a simulator for individual trainees prohibitive. For instance, the VRS used in this trial is commercially available for $60000 to $100000 [31] while the box trainer is commercially available for £420 [32]. Moreover, box trainers are well received by trainees who find them to be useful [30,33].

It may be notable that the group practicing using a box trainer has performed better during the assessment on the virtual reality simulator than the group practicing on the VR simulator. This could be attributed to the transferability of skills gained in box trainers to virtual reality simulators, something that was previously established by other authors [34].

Improvement in GOALS score was found to be non statistically significant for both inter and intra comparisons with the exception of the efficiency category. Alike results were noticed when operating room performance was assessed for the purposes of validating laparoscopic simulators. Two of the possible reasons proposed by the authors were small sample size and introduction of the didactic intervention too late in the learning curve [35]. These are applicable in our study as the number of participants who completed the study is limited and participants were not complete novices. Nevertheless there are several studies demonstrating that 30-40 operations are necessary prior to achieving proficiency for laparoscopic cholecystectomy, therefore the trainees participating in our trial are not experts [36-38], however, recruitment of complete novices may have demonstrated a more augmented difference in the impact of BT and VR training.

The two training methods have rarely been compared to each other, therefore it is difficult to come to safe conclusions as to which method is better [13,39]. However, some studies have shown that box trainers have equal [24] or superior didactic effect when compared to virtual reality simulators [23]. Further, in the rare occasions that this comparison has taken place, important factors about the practicalities of training on a VR simulator such as access and need for initial training have not been taken in to account [24,23], albeit, these have been shown to be significant obstacles to the utilisation of this technology [28-30].

This study has some limitations. The drop-out rate (6 of 22) is significant. Perhaps a shorter training period could contribute towards reducing the drop-out rate. Unfortunately, this is a rather frequent occurrence in educational studies [20,3,19,35,2]. Assessing the clinical impact of the study is methodologically challenging, as a number of participants did not have the opportunity to perform real laparoscopic cholecystectomies immediately after the completion of the study. Surgical interns within the British training system undergo six-month clinical placements in various surgical specialties other than general or upper gastrointestinal surgery; this was the case for seven of the participants of the trial who were therefore deprived the opportunity to practice their newly acquired skills. Consequently, any evaluation of the clinical impact with respect to the number of real procedures performed after the study would be inaccurate.

In conclusion, the current study shows that “take-home” box trainers are a potential alternative to VR simulators. The former are an attractive option for surgical training as they are more portable and cost-effective and can therefore be provided to each trainee at the beginning of their training with reduced financial burden on their local hospital.

Tables:

Group	Variable	Baseline median/mean	Post-training median/mean	P-value
BT	TT (sec)	1505	317	0.008
	NOM	1419	430	0.008
	PL (cm)	2927	1335.9	0.008
VR	TT (sec)	1234	837	0.018
	NOM	968	584	0.063
	PL (cm)	2179	1209.9	0.128

Table 1. Comparison of performance between baseline and post-training. Paired t-test and Wilcoxon test was used to compare continuous metrics (PL) and discrete data (TT, NOM) respectively.

Variable (improvement in)	BT (median/mean)	VR (median/mean)	p-value
TT (sec)	968	401	0.005
NOM	731	264	0.042
PL (cm)	1887.3	616.4	0.031

Table 2. Inter-group comparison of improvement from baseline to post-training assessment. T-test used for continuous variables and Mann-Whitney test for discrete.

Group	Category	Baseline median/mean	Post-training median/mean	P-value
BT	Depth Perception	4	4	0.23
	Bimanual Dexterity	4	4	0.18
	Efficiency	2.5	3.5	0.03
	Tissue Handling	3	4	0.24
	Overall	13	14	0.74
VR	Depth Perception	4	4	0.68
	Bimanual Dexterity	4	3	0.08
	Efficiency	3	3	0.78
	Tissue Handling	4	4	0.38
	Overall	15	15.5	0.40

Table 3. Intra-group comparisons of GOALS scores*. Wilcoxon test was used for these comparisons.

Improvement in	BT group (median)	VR group (median)	P-value
Depth Perception	0.5	0	0.61
Bimanual Dexterity	0	0	0.55
Efficiency	1	0	0.09
Tissue Handling	-1	-1	0.84
Overall	0	-0.5	0.35

Table 4. Inter-group comparisons of improvement in GOALS score*. Mann-Whitney test was used for these comparisons.

* Modified GOALS score categories: Depth perception -1- Constantly overshoots target, wide swings, slow to correct -3- Some overshooting or missing of target, but quick to correct -5- Accurately directs instruments in the correct plane to target. Bimanual dexterity -1- Uses only one hand, ignores non dominant hand, poor coordination between hands -3- Uses both hands, but does not optimize interaction between hands -5- Expertly uses both hands in a complimentary manner to provide optimal exposure. Tissue handling -1- Rough movements, tears tissue, injures adjacent structures, poor grasper control, grasper frequently slips -3- Handles tissues reasonably well, minor trauma to adjacent tissue (ie, occasional unnecessary bleeding or slipping of the grasper) -5- Handles tissues well, applies appropriate traction, negligible injury to adjacent structures[17].

Figure legends

Figure 1. Results of intra and inter group comparisons. The synthetic and virtual simulators used for the study can be found on the lower left and right side of the figure respectively.

Figure 2. Box trainer

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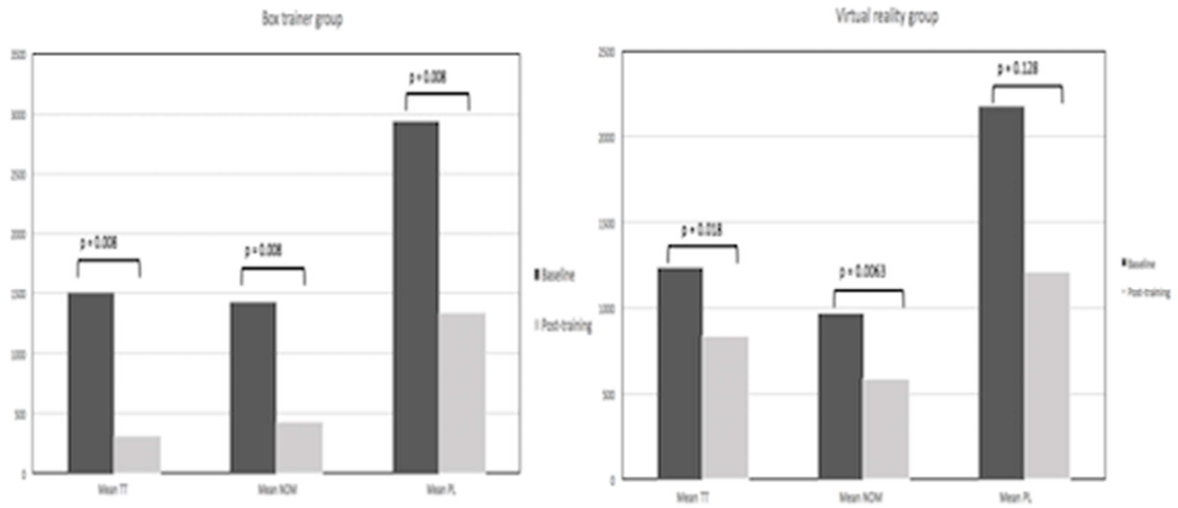
Improvement in	BT group (median)	VR group (median)	P-value
Depth Perception	0.5	0	0.61
Bimanual Dexterity	0	0	0.55
Efficiency	1	0	0.09
Tissue Handling	-1	-1	0.84
Overall	0	-0.5	0.35

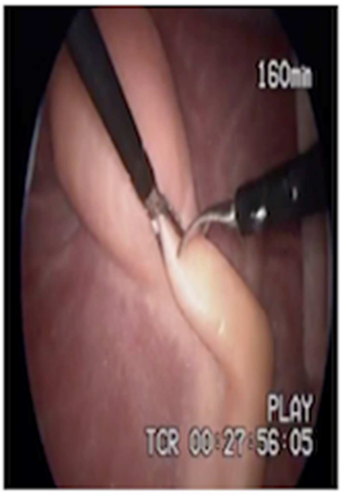
Table 4. Inter-group comparisons of improvement in GOALS score*. Mann-Whitney test was used for these comparisons.

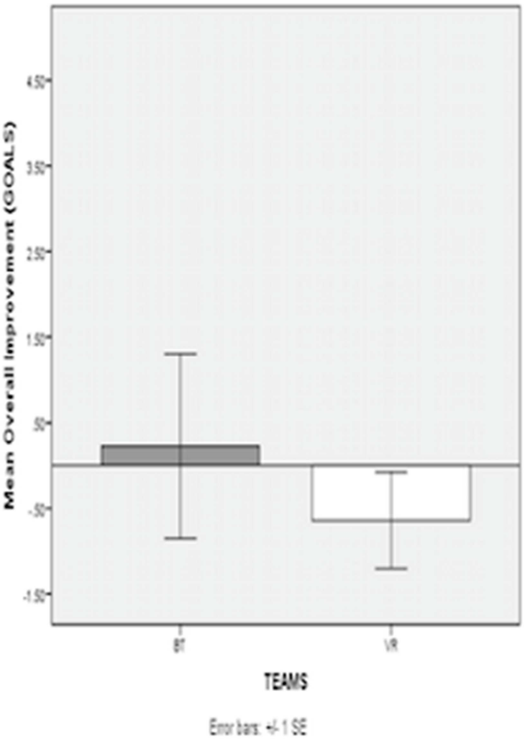
* Modified GOALS score categories: Depth perception -1- Constantly overshoots target, wide swings, slow to correct -3- Some overshooting or missing of target, but quick to correct -5- Accurately directs instruments in the correct plane to target. Bimanual dexterity -1- Uses only one hand, ignores non dominant hand, poor coordination between hands -3- Uses both hands, but does not optimize interaction between hands -5- Expertly uses both hands in a complimentary manner to provide optimal exposure. Tissue handling -1- Rough movements, tears tissue, injures adjacent structures, poor grasper control, grasper frequently slips -3- Handles tissues reasonably well, minor trauma to adjacent tissue (ie, occasional unnecessary bleeding or slipping of the grasper) -5- Handles tissues well, applies appropriate traction, negligible injury to adjacent structures[17].

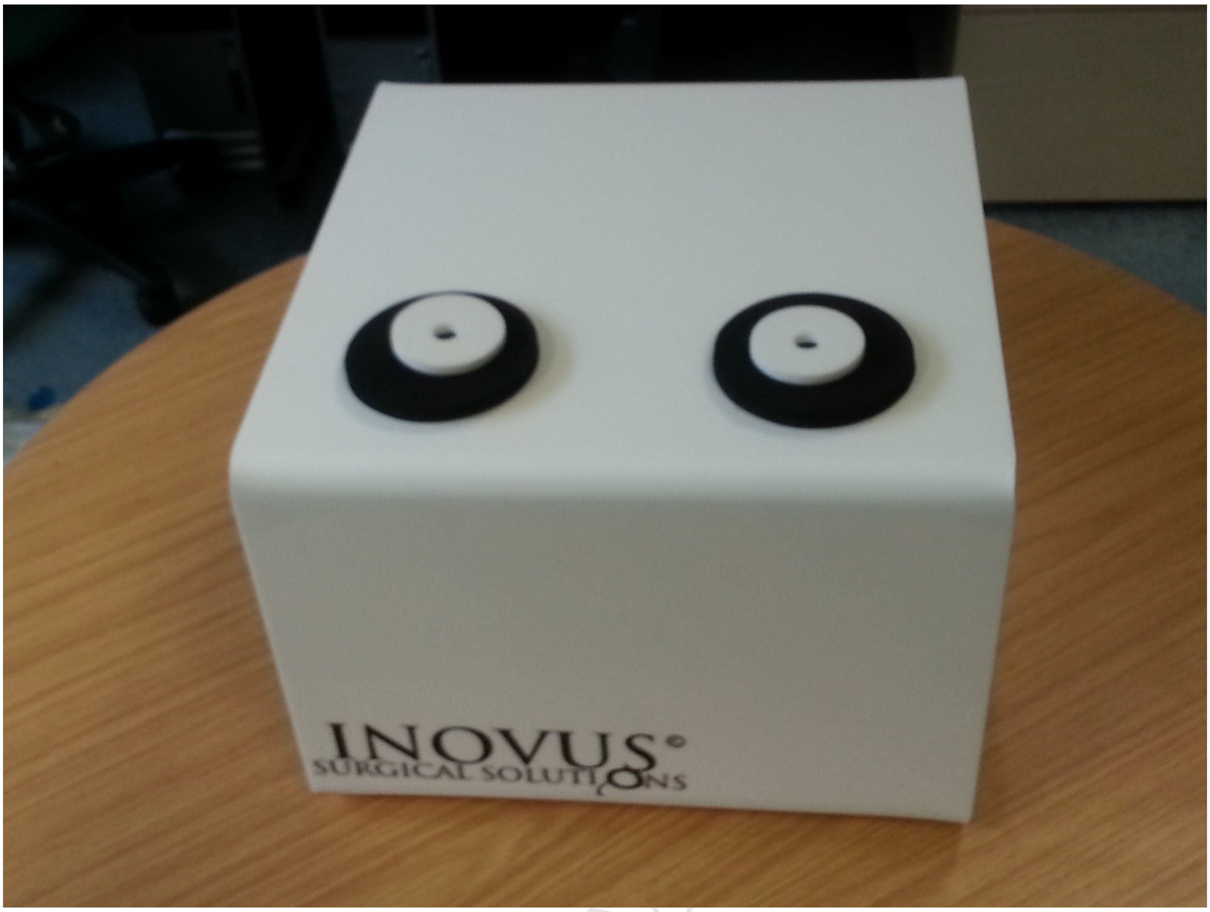
Performance before and after six-week practice



Box trainer group vs. Virtual reality group



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