

## Title

**How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses? A systematic review.**

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## Abstract

### Introduction

Simulated practice, both face-to-face and computer-based, is well established within healthcare education, allowing rehearsal and refinement of clinical skills. Virtual reality is a new and relatively untested method of delivering simulation learning.

### Aims

This project aims to systematically review, critically appraise and synthesise the published evidence in order to answer the question 'How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses?'

### Methods

The databases CINAHL, Medline, Psychinfo, PubMed and the University of Portsmouth 'Discover' database were searched between 4th June 2018 and 7th July 2018 using the terms; pre-registration, pre-licensure, "pre registration", "pre licensure", trainee, student, students, nurs\*, virtual-reality, VR, "virtual reality", "augmented reality", clinical, skill\*, competenc\* and mastery. Inclusion and exclusion criteria relating to type of paper, population, intervention, comparison and outcome were applied. Selected articles were appraised using the Centre for Reviews and Dissemination guidelines. As clinical psychomotor skill mastery requires the application of theoretical knowledge to a motor skill in a range of contexts, outcomes relating to these elements (namely knowledge, cognitive gain, skill performance, skill success and time to complete) were analysed.

### Findings

Nine studies were included in the review. All studies employed a quasi-experimental design but were of mixed methodological quality. There was significant heterogeneity in methods and missing data, limiting synthesis and precluding meta-analysis. Virtual reality groups performed favourably in comparison to simulation groups in posttest knowledge scores, cognitive gain, skill performance scores and skill success rate. There was divergence of results in relation to time taken to complete the skill.

### Discussion

Whilst the results are generally favourable for virtual reality, variation in devices, data collection tools and outcome measurements mean that caution must be used in their interpretation. Outcomes relating to psychomotor skill performance support the use of virtual reality as an educational intervention. Time taken to undertake and complete the skill is

questioned as a valid outcome measurement due to the potential to forgo skill accuracy in favour of speed.

## Conclusion

Virtual reality is an emerging technology with a limited body of evidence, which is of variable methodological quality. It appears that virtual reality leads to educational outcomes similar or superior to traditional simulated practice. Consensus in definitions is needed along with further research to advance knowledge of this developing area of practice. Such research is needed to justify the cost of investing in this new technology.

## Keywords

Education, pre-registration nursing, systematic review, simulation, skill, virtual reality

## Contribution of the Paper

What is already known about this topic?

- Clinical psychomotor skill acquisition is a key component of pre-registration nurse education.
- Simulated clinical practice, within skills laboratory settings is an effective method of acquiring such skills, but has a number of important limitations.

What this paper adds.

- This review shows that there is a limited evidence base of mixed methodological quality comparing virtual reality simulation to traditional simulated clinical practice.
- The evidence base suggests that virtual reality simulation leads to similar outcomes to traditional simulated clinical practice.

## Introduction

The acquisition of clinical psychomotor skill is an integral part of any pre-registration nursing programme. Traditionally taught in clinical practice or in simulated clinical practice, psychomotor skill mastery comprises the application of theoretical knowledge to a motor skill in a range of contexts (Fotheringham 2010, Sawyer et al., 2015). Indeed Fotheringham (2010) asserts that cognitive and motor skills are inextricably linked within psychomotor skill acquisition. For example, the skill of recording blood pressure requires not only knowledge of and competence in performing the component steps, but a deep understanding of the underpinning theory in order that the practitioner may adapt the skill to suit the context (such as an anxious patient or a patient with limited mobility). Learning skills in clinical practice could be seen as the gold standard, however a widely recognised 'theory-practice gap' suggests that this alone is insufficient to prepare students for the role of newly qualified

nurse (Huisman & Case, 2016; Josephine Scully, 2011; Monaghan, 2015). Learning via simulated clinical practice is viewed as one way of addressing this gap (Josephine Scully, 2011; Monaghan, 2015) and has many advantages, not least avoiding the potentially disastrous consequences of mistakes being made in real life clinical practice settings (Lewis et al., 2012).

Traditional simulated practice takes place within skills laboratories, using mannequins, part task trainers and human actors to replicate clinical scenarios or discrete procedural tasks (Weller, Nestel, Marshall, Brooks, & Conn, 2012). In addition, computer based simulation plays an important role within healthcare education, with a range of software applications and 'serious games' being used as an adjunct to, or replacement for face-to-face training (Wang et al 2016, Donovan et al 2018). Aligning closely to experiential learning theory (Kolb, David A., Boyatzis, Richard, E., Mainemelis, 2000; Kolb, 1984), simulated practice allows the learner to partake in a concrete event, reflect on the experience, identify what may have been done differently, and actively experiment, allowing the learning to shape future practice (Poore, Cullen, & Schaar, 2014). Despite the clear advantages of simulated practice, there are a number of potential barriers to learning including fear of technology (Al-Ghareeb & Cooper, 2016), cognitive load, heightened emotion (Fraser et al., 2012), and, rarely, pediophobia or a fear of mannequins (Macy & Schrader, 2008). In addition there are also organisational barriers including faculty training, initial costs and the on-going resource burden of equipment, environments and staffing (Al-Ghareeb & Cooper, 2016). These organisational barriers often lead to limited opportunities for learners to participate in such activities.

Virtual Reality, in which the user is 'immersed in and able to interact with a synthetic world' (Milgram & Kishino, 1994) offers an enticing opportunity to offer simulated learning experiences in a novel and engaging way (Bailenson et al., 2008; Johnson-Glenberg, 2018). The potential to ameliorate some of the individual and institutional barriers identified above, with reduced resource intensity and emancipation from the skills lab is attractive, however, before investing in new technology it is imperative to assess its feasibility and effectiveness as an educational method. Hence the genesis of this review and its broad aim to consider whether the existing evidence base supports the use of virtual reality as an educational intervention within the author's field of nursing education.

### *Scoping searches & definition of terms*

As an emerging technology, the literature around virtual reality as an educational intervention is relatively limited. Scoping searches revealed papers relating to its use as a

clinical intervention (Juras et al., 2018; Levy et al., 2018), in medical training (Vaughan, Dubey, Wainwright, & Middleton, 2016) and within nursing and allied healthcare education (Hammer & Souers, 2004; Ulrich, Farra, Smith, & Hodgson, 2014), with much of the education and training research focused on high risk, invasive skills such as endoscopy and surgery (Khan et al., 2018; Samadbeik et al., 2018).

In completing this study it became clear that there is an emerging lexicon with a bewildering array of terminology around virtual reality and a number of terms being conflated in the literature and by educators (Galvan-Debarba et al., 2017). The plethora of terms include mixed reality, augmented reality, augmented virtuality, (Milgram & Kishino, 1994) multimediated reality (Mann, Furness, Yuan, Lorio, & Wang, 2018), virtual patient, virtual world and virtual reality (Chiniara et al., 2013). In the absence of widely accepted definitions, working definitions [**SUPPLEMENTARY MATERIAL TABLE 1**] were developed to create clarity within the study and the report. From these, virtual reality can be defined as an immersive experience whereby the user interacts with a video or computer generated simulation from a first person viewpoint using a monitor or headset device with or without haptics devices. This definition was based on the notions of 'presence' and 'embodiment' as these are suggested to be the key unique attributes of virtual reality that positively affect education (Johnson-Glenberg, 2018). These concepts are strongly related to an egocentric first person experience in which coherent multisensory integration occurs within the user's brain (Galvan-Debarba et al., 2017) making an immersive and realistic experience for the user.

Using these concepts, it is clear that not all that purports to be virtual reality would meet this review's definition. For example many healthcare education projects employ a 'virtual world' such as Second Life® as their intervention (Liaw et al., 2018). Within such interventions users explore a computer generated environment via an on screen avatar, meaning they are experiencing it from the third person perspective. Whilst undertaking initial scoping searches it became apparent that a number of papers describe their use of virtual worlds as virtual reality, however the third person perspective can be a barrier to embodiment (Galvan-Debarba et al., 2017) and therefore they would not meet this review's criteria to be termed virtual reality.

In order to frame a clear and answerable research question it is recommended to use a model such as PICO, PICOSS or SPIDER (Methley, Campbell, Chew-Graham, McNally, & Cheraghi-Sohi, 2014). As the aim of this study is to explore the relationship between virtual reality and the acquisition of clinical psychomotor skill, the PICO model was most appropriate (Boland, Cherry & Dickson, 2017). This model requires you to identify the

following elements of interest to the researcher - population, intervention, comparison and outcome. These can then be structured into a question that will form the basis of the study.

P - pre-registration nursing students

I - virtual reality

C - simulated clinical practice

O - clinical skill acquisition

Combining these terms led to the following question 'How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses?'

## Methods

Boland, Cherry, & Dickson's (2017) ten-step process was used to frame this review. Internationally recognised guidance by way of the Centre for Reviews and Dissemination (2008) core principles and methods for conducting a systematic review, and the PRISMA statement for reporting systematic reviews and meta-analyses of studies (Liberati et al., 2009) were also consulted throughout.

### *Search strategy:*

The Centre for reviews and dissemination and the Cochrane Library databases were searched for any existing systematic reviews answering this project's question. They were then searched using the terms 'virtual reality' for any papers which might meet the inclusion criteria. No systematic reviews or relevant papers were found. Broad scoping searches were then undertaken to identify appropriate databases and search terms.

Search terms were formulated according to the keywords previously identified with the PICO model, and synonyms were determined with the use of a thesaurus. Phrases were encompassed within quotation marks to ensure that the search would specifically look for this entire phrase as written, and the truncation symbol \* was used to allow the search for multiple words beginning with the same root (MIT Libraries, n.d.). It was decided to include augmented reality as a search as although this was not the topic of interest, some papers may have used this term to describe interventions which meet the criteria to be virtual reality within this review.

The following databases were included within the search: CINAHL, Medline, Psychinfo, PubMed and the University of Portsmouth library 'Discover' database. Boolean operators were employed to search for all synonyms using OR, and to combine terms using AND, leading to a search for papers which included at least one of the synonyms from each PICO criteria (table 1).

Pre-registration OR pre-licensure OR "pre registration" OR "pre licensure" OR trainee OR student OR students	
AND	nurs*
AND	Virtual-reality OR VR OR "virtual reality" OR "augmented reality"
AND	Clinical OR skil* OR competenc* OR mastery

Table 1. Boolean operator search

The following inclusion and exclusion criteria were developed to screen potential articles for inclusion within the study (table 42). These were again aligned to the PICO framework to ensure papers with the appropriate populations, intervention, comparison and outcome were included. In addition, the search would be limited to research papers alone, and as the study question is looking to explore the relationship between the intervention and outcome as opposed to stakeholder experience and perception, papers would be limited to those employing hypothetical-deductive research methodologies. Due to the newness of the technology it was decided that placing date restrictions on the search would be redundant.

The search was conducted by a single reviewer and as such there was no verification of selected papers. This is acknowledged as a major limitation of this review and is discussed within the limitations section of this paper.

Inclusion	Exclusion
Published in English language	Not published in English language
Research paper	Non-research papers, i.e. letters to the editor, editorials
Full study report, published within a peer reviewed academic journal	Not published in peer reviewed journal, or full study report not available.
Full text available online or via library (including inter-library loan)	Full text not available
Study population is pre-registration nursing	Study population is not pre-registration

students	nursing students
Intervention meets review definition for virtual reality  I.e. is computer based, immersive '1st person' virtual reality technology using a virtual reality headset or monitor +/- haptic device in which the student directly interacts with a simulated environment intended to replicate the real world	Does not meet the review definition of virtual reality  I.e. is not computer based, immersive '1st person' virtual reality technology using a virtual reality headset or monitor +/- haptic device in which the student directly interacts with a simulated environment intended to replicate the real world
Comparison is non-virtual reality simulated practice using simulated patient, mannequin or part-task trainer +/- classroom or computer-based didactic teaching	Comparison is not simulated practice using simulated patient, mannequin or part-task trainer +/- classroom or computer-based didactic teaching
Outcome(s) measured comprise elements of psychomotor skill, ie. underpinning knowledge and/or skill performance	Outcome(s) measured do not comprise elements of psychomotor skill, ie. underpinning knowledge and/or skill performance

Table 2. Inclusion and exclusion criteria.

### *Data extraction, quality assessment and synthesis*

Once the final articles for review were obtained, a data extraction form was developed and piloted to abstract key study characteristics and results (Boland, Cherry & Dickson, 2017). Methodological quality of each article was assessed according to Centre for Reviews and Dissemination (2008) guidelines. Results were then tabulated and analysed using a narrative synthesis approach (Boland, Cherry & Dickson, 2017).

## Results

### *Search results*

Databases searches were carried out between 4th June 2018 and 7th July 2018. Reference lists of the full text articles were also examined for potentially relevant articles which were then screened against the inclusion and exclusion criteria. Initial database searches revealed 407 papers, with a further 214 identified from the reference lists of full text articles. After removal of duplicates, a total of 462 records remained. Titles and abstracts were screened against the inclusion/exclusion criteria and where it was unclear whether these were met, the full-text article was retrieved for further screening. 60 full text articles were screened, of which nine had to be requested via inter-library loan. 51 articles were excluded as they did not meet inclusion/exclusion criteria leaving nine articles for inclusion in the

review [SUPPLEMENTARY MATERIAL TABLE 2]. The complete search is laid out in figure 1.

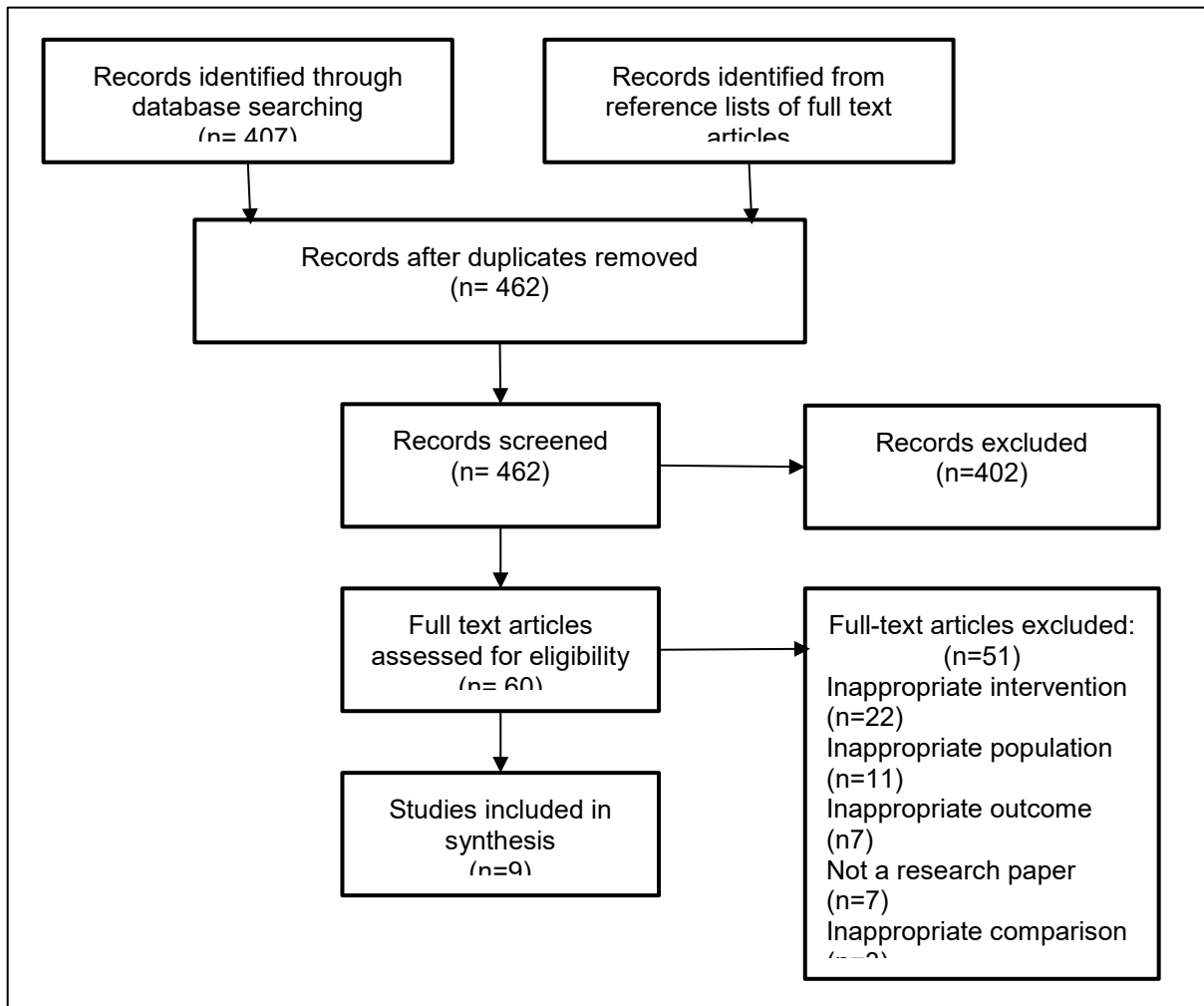


Figure 1. Search results. Based on PRISMA flowchart (Moher, D., Liberati, A., Tetzlaff, J., Altman, D., The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *British Medical Journal*. Vol. 339 pp.2535)

### Quality assessment

All of the studies employed a randomised quasi-experimental approach, one within a larger mixed methods design, therefore evidence appraisal tools aimed at this methodology were considered for use. A number of relevant appraisal tools were examined including the Critical Skills Appraisal Programme (CASP), checklist (2016). Although widely used in evidence based medicine, this tool was less appropriate to this review due to its focus on health outcomes and the lack of mixed methods appraisal tool. The Centre for Reviews and Dissemination (2008) guidelines cover a broad range of reports and publications and were



found to be more relevant to this review. These were therefore modified to focus on the population of interest and used to guide the appraisal of the studies.

Results of the appraisal [**SUPPLEMENTARY MATERIAL TABLE 3**] demonstrate a picture of mixed methodological quality. Only three studies met or partially met all criteria (Butt, Kardong-Edgren & Ellertson 2018, Gunay-Ismailoglu & Zaybak 2018, Jung et al 2012), thus demonstrating higher quality and greater rigor by minimising potential biases and confounding factors (Centre for Reviews and Dissemination 2008). For the remaining six studies, key elements were unreported or only partially reported, making an assessment of rigor impossible. Although it is not possible to rate these as high quality evidence, one must keep in mind that although criteria were not reported they may have been met, however caution must be used when applying their evidence.

#### *Data extraction*

A data extraction form was built within the Google Form® platform to capture study characteristics, sample characteristics and study results (Boland, Cherry & Dickson, 2017). This was piloted using 4 of the selected studies and subsequently amended and refined to ensure that all relevant data were obtained. In order to answer the review question, data relating to the PICO keywords and outcomes relating to both the cognitive and motor elements of psychomotor skill (knowledge and skill performance) were extracted.

#### *Study characteristics*

The papers were published between 2003 and 2018 and were conducted in a number of countries; four in the USA, two in Kuwait and one in Turkey, with the study setting undisclosed in the remaining two papers. As previously noted, all of the studies used a quasi-experimental randomised control trial (RCT) approach, one within a larger mixed methods study. Five studies adopted a pre and posttest design with four opting for posttest only.

Whilst all of the studies compared virtual reality with simulation in nursing students, there was variation in the nature of the virtual reality intervention, data collection tools employed and outcomes measured between studies. As might be expected from the search strategy, the method of comparison was the same in all studies. Notably, the skill being taught was also surprisingly consistent, with seven studies focused on venepuncture and two concerned with urethral catheterisation, both being dexterous technical skills. The two studies investigating urethral catheterisation both employed a virtual reality headset, with one also utilising a haptic device. The seven venepuncture studies used a monitor with a haptic

device. All nine studies compared the intervention with traditional instruction using a mannequin or part-task trainer. Participant characteristics demonstrate reasonable homogeneity between studies; while outcomes are discussed in detail in study results below.

*Study results*

Due to significant heterogeneity in study designs and outcome measurements it would be inappropriate to attempt meta-analysis of results (Boland, A Cherry, M , Dickson, 2017), furthermore data were under-reported in many of the studies.

*Knowledge*

Knowledge was measured and reported in four studies (table 3), in all cases by means of a written examination in which higher scores suggested superior knowledge. In three of the studies pre and posttest knowledge scores were measured allowing a calculation of cognitive gain, or the knowledge based learning between tests. The study by Engum, Jeffries, & Fisher (2003) reported posttest knowledge scores alone, and only for the intervention group, so these data were excluded from the synthesis. Meta-analysis was not possible due to incomplete data sets across studies.

Study	Mean pretest knowledge score			Mean posttest knowledge score			
	virtual reality group n (SD)	Simulation group n (SD)	3rd group (if applicable) n (SD)	virtual reality group n (SD)	Simulation group n (SD)	3rd group (if applicable) n (SD)	Significance
Butt et al (2018)	na	na	na	ns	ns	na	ns

Davis-Reyes et al (2008)	67	64	na	76.92	80	na	p=0.00 t=-5.414*
Engum et al (2003)	ns	ns	na	16.38	ns	na	ns
Gunay-Ismailloğlu & Zaybak (2018)	33.55 (10.83)	30.53 (13.56)	na	66.15 (13.25)	65.56 (12.91)	na	p=0.783 z=0.276**
Jamison et al (2006)	9.4	10.56	na	10.9	10.78	na	ns
Jung et al (2012)	na	na	na	na	na	na	na
Smith & Hamilton (2015)	na	na	na	ns	ns	na	ns
Vidal et al (2013)	na	na	na	na	na	na	na
William et al (2016)	na	na	na	na	na	na	na
NS = not stated, na = not applicable *t test **Mann-Whitney U test <b>NB range of available scores only given for Gunay-Ismailloğlu &amp; Zaybak (2018) so unable to calculate standardised means</b>							

Table 3. Participants' mean pre and post intervention knowledge test scores

Of the three studies, two demonstrated higher mean posttest knowledge scores in the virtual reality group compared to the simulation group (Davis-Reyes et al 2008 and Gunay-Ismailloğlu & Zaybak 2018), with only Davis-Reyes et al (2008) demonstrating statistical significance (p=0.00). Similarly, in the calculation of cognitive gain [**SUPPLEMENTARY MATERIAL TABLE 4**] two studies achieved higher mean differences in the virtual reality groups (Davis-Reyes et al 2008, Jamison et al 2006) demonstrating a greater improvement in knowledge over time in these groups. It is however noteworthy that while Davis-Reyes et al. (2008) demonstrated higher cognitive gain in the virtual reality group, this group obtained a lower score than the simulation group in the posttest measurement, showing that although they showed a greater increase in knowledge, their overall test scores were inferior to the simulation group. The opposite effect was seen in Günay Ismailloğlu & Zaybak (2018).

### *Skill performance*

Four studies failed to report skill performance scores despite indicating that this outcome was measured (table 4). Of those who reported these scores, students demonstrated the skill on either a mannequin or a human subject and their performance was assessed by a trained observer. Within each of these studies, skill performance was assessed and marked against set criteria with higher scores signifying better application of the skill. Two studies showed statistically significant higher mean scores among the virtual reality group. It is of note that in these studies, student performance was demonstrated on a simulation

mannequin. Conversely, students in the Jung et al (2012) study undertook the skill on human subjects and the virtual reality group showed a statistically significant lower mean score than those in the simulation group.

Study	Mean skill performance score			Significance
	Virtual reality group n (SD)	Simulation group n (SD)	3rd group (if applicable) n (SD)	
Butt et al (2018)	NS	NS	na	na
Davis-Reyes et al (2008)	na	na	na	na
Engum et al (2003)	NS	NS	na	na
Gunay-Ismailoglu & Zaybak (2018)	33.73 (4.22)	26.53 (4.45)	na	z= 5.294
Jamison et al (2006)	NS	NS	na	na
Jung et al (2012)	31.79 (3.59)	32.79 (3.58)	34.08 (2.98)	p=0.015
Smith & Hamilton (2015)	94.92 (6.54)	92.77 (16.63)	na	p= .005 t= 0.821*
Vidal et al (2013)	NS	NS	na	na
William et al (2016)	na	na	na	na
NS = not stated na = not applicable *t test **Mann-Whitney U test <b>NB range of available scores only given for Jung et al (2012) so unable to calculate standardised means</b>				

Table 4. Participants' mean skill performance score on a mannequin or human after intervention

### *Skill success*

The number of participants who were able to successfully demonstrate the skill (as defined by each study) was measured in seven studies and reported in six [**SUPPLEMENTARY MATERIAL TABLE 5**]. Skill success was defined within each study as the student achieving the identified objective of the skill being demonstrated, for example accurate placement of the catheter within the bladder. In two of these studies the skill was undertaken on a mannequin, and on a human in the other four. Success rate was identical between groups in three cases, and higher in the virtual reality group in two studies, one using mannequins (Smith & Hamilton 2015) and one human (Jung et al., 2012). One study (Davis-Reyes et al., 2008) showed a higher success rate in the simulation group versus the virtual reality group. None of the studies reported statistically significant results or provided an estimate of effect size.

### *Time to complete skill*

Time taken to complete the skill was measured in three studies and reported in two (Jung et al., 2012; William, Vidal, & John, 2016) [**SUPPLEMENTARY MATERIAL TABLE 6**]. In both cases the skill was undertaken on a human. In the Jung et al. (2012) study, participants in the virtual reality group took longer to complete the skill than those in the simulation group, with a mean completion time of 182.79 seconds (SD 48.63) versus 164.11 seconds (SD 65.09), a result that was statistically significant ( $p=0.007$ ). Conversely in the William et al. (2016) study the virtual reality group completed the skill faster than the simulation group, with a mean completion time of 807.0 seconds (SD 773.64) versus 1240.2 seconds (SD 1243.68) however this result failed to reach statistical significance ( $p=1.01$ ).

## Discussion

It is important when considering the results to revisit the review question (Gough et al., 2017). In this review this was “How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses?”. The relatively small number of studies found, compounded by the mixed methodological quality impacts the degree to which the question can be answered with certainty. In addition there was significant heterogeneity in the methods used and missing data, limiting synthesis and precluding meta-analysis. Despite these limitations, it is possible to draw some tentative conclusions from the findings.

Although the methods employed varied between studies, students using virtual reality to learn and rehearse skills demonstrated an increase in knowledge test scores after experiencing the intervention. The amount of change in knowledge score, denoting the degree of learning or cognitive gain, was comparable with those students who experienced traditional simulated practice. This suggests that both approaches afford students an opportunity to contextualise and strengthen their theoretical knowledge by learning through experience (Poore, Cullen, & Schaar, 2014). In addition to cognitive knowledge, virtual reality groups performed comparably to simulation groups in skill performance scores and skill success rate. Although individual studies had weaknesses, when viewed together these findings are given additional weight as they were broadly consistent across studies. It can therefore be tentatively concluded that virtual reality as an educational intervention leads to measurable improvement in knowledge and the application of that knowledge, the two requisites of clinical psychomotor skill mastery (Sawyer et al., 2015). Furthermore, these improvements are comparable with those seen in traditional simulation.

There was divergence of results in relation to time taken to complete the skill, albeit this outcome was only reported in two studies. One study found that the virtual reality group took considerably longer than the simulation group, however this result failed to reach statistical significance. Notwithstanding these obvious limitations, It is also worth considering whether results have any significance in terms of application to the practical context. Although being able to perform clinical skills in a timely and efficient manner is seen favourably, it is clearly of greater importance that it be performed correctly. The trade-off between speed and accuracy could lead to errors or omissions in the process (Beilock et al., 2008), or to a less satisfactory experience for the patient and therefore it should be questioned whether this outcome is potentially irrelevant or misleading.

## Limitations

There are a number of limitations within this study, not least the significant heterogeneity between studies. Studies employed a number of different virtual reality devices, with variation in the method of viewing via monitor or headset and whether haptic feedback devices were incorporated. There has also been significant developments in the fidelity and capability of virtual reality technology over the 15 year span of the studies. Both of these factors are likely to mean important differences in the experiences of participants across studies. As has already been noted, variation in outcomes measured and unreported data inhibit synthesis. Although the studies purported to be investigating learning, only three studies undertook a pre and posttest approach, and then only for knowledge, limiting the degree to which we can be confident that the intervention led to cognitive or psychomotor skill gain.

This review was carried out by a single researcher with limited resource and academic and time constraints. As a result there was no inter-rater calibration of the search strategy and application of inclusion/exclusion criteria, data collection tool or data extracted, thus impacting the validity and reliability of these aspects. Due to limited resources and time constraints, the researcher did not contact authors of the selected articles to enquire about missing data. This could have allowed a more thorough analysis, greater synthesis and a more complete assessment of methodological quality. Furthermore, a hand search of relevant journals was not conducted, which may potentially mean that some pertinent articles were not included in the review. Finally, the researcher was only able to report on studies that have been published, leading to publication bias (Centre for Reviews and Dissemination 2008).

## Conclusion

As a highly practical profession, nursing will continue to need experiential, skills based learning, blended between the classroom and the clinical setting. Traditional simulated practice in a skill laboratory is a well embedded and researched teaching and learning strategy shown to address the gap between theoretical knowledge and psychomotor skill performance. virtual reality is an emerging technology with the potential to address some of the barriers to traditional simulated practice, however a shared language and consensus around definitions must be developed in order to facilitate continued discourse in this area. Although the literature in this area is in its infancy, the findings from this review give rise to cautious optimism over the effectiveness of virtual reality as an educational intervention in relation to psychomotor skill acquisition. More research of high methodological quality is needed to increase confidence in this conclusion.

At present, much of the literature is focused on technical skill acquisition, and then within a narrow range of skills, with little examining the application of virtual reality to non-technical skill. Similarly, it is imperative to understand not only whether this form of intervention is effective, but whether it is acceptable to faculty and learners alike. Therefore, there is much still to explore in order to gain a fuller understanding of how and why this approach to learning might be employed.

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