University of Groningen

Fostering oral presentation competence through a virtual reality-based task for delivering feedback

van Ginkel, Stan; Gulikers, Judith; Biemans, Harm; Noroozi, Omid; Roozen, Mila; Bos, Tom; van Tilborg, Richard; van Halteren, Melanie; Mulder, Martin

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

[Link to publication in University of Groningen/UMCG research database](#)

Fostering oral presentation competence through a virtual reality-based task for delivering feedback

Stan van Ginkel[a,b,*], Judith Gulikers[b], Harm Biemans[b], Omid Noroozi[b], Mila Roozen[c], Tom Bos[d], Richard van Tilborg[e], Melanie van Halteren[e], Martin Mulder[b]

[a] VR Lab of the Archimedes Institute, Hogeschool Utrecht, University of Applied Sciences, bode 68, P.O. Box 8130, NL 6700 EW, Wageningen, the Netherlands
[b] Department of Education and Learning Sciences, Social Sciences Group, Wageningen University & Research, bode 68, P.O. Box 8130, NL 6700 EW, Wageningen, the Netherlands
[c] Groningen Institute for Evolutionary Life Sciences, Department of Behavioural Neuroscience, University of Groningen, P.O. Box 11103, 9700 CC, Groningen, the Netherlands
[d] NCOI Education Management, Box 447, NL 1200 AK, Hilversum, the Netherlands
[e] CoVince, Adventurous Learning, Reyer Anslostraat 28, 3522 DJ, Utrecht, the Netherlands

ARTICLE INFO

ABSTRACT

While previous studies have stressed the importance of feedback delivered by experts, it is unclear whether students' oral presentation competence can be fostered through innovative technology for delivering feedback. This experimental study examined the effectiveness of a virtual reality-based task, in which first-year undergraduate students practiced their presentation in a virtual environment and received feedback produced by the system, on their presentation competence components (i.e. cognition, behaviour and attitudes towards presenting). The effects were compared with a control condition, which was a face-to-face presentation task with expert feedback. The students' performance was measured using pre- and post-test multiple-choice tests, validated rubrics, and self-evaluation instruments. Results revealed significant improvements from pre-test to post-test in all three presentation competence components, without a difference between the conditions. Furthermore, the self-evaluation tests showed that students who presented in virtual reality were appreciative of the detailed and analytical feedback they received. Because of sample size limitations, the effects found could not be generalised. Therefore, future research on a larger sample is needed to examine population effects. Follow-up studies should focus on the extent to which virtual reality-based tasks can encourage self-regulation skills for the effective and efficient integration of these tasks in presentation courses.

1. Introduction

Presenting is a core competence of the highly-educated professional (De Grez, 2009; Kerby & Romine, 2009). It is a prerequisite for successful performance in various working environments and for effective communication in democratic societies (e.g. Chan,

---

2011; Reitmeier & Vrchota, 2009; Smith & Sodano, 2011). Although considered by educational policymakers to belong to the primary skills set of graduates (Washer, 2007), young professionals often fail to acquire public speaking capabilities (Chan, 2011). Furthermore, presenting is frequently named by individuals as one of their main fears in social contexts (Smith & Sodano, 2011).

A potential means to reduce fear when presenting is to develop students' oral presentation competence. Oral presentation competence in this research field can be defined as *'a combination of knowledge, skills and attitudes needed to speak in public in order to inform, self-express, relate, or to persuade'* (De Grez, 2009, p. 5). Students' presentation performance can be fostered or restricted by any or all of the three components referring to cognition, behaviour and attitudes towards presenting (e.g. Mulder, 2014; Mulder & Winterton, 2017; Van Ginkel, Gulikers, Biemans, & Mulder, 2015a). For example, presenters who acquire knowledge about how to present may improve their skills, and this may make them more eager to speak in public (Bower, Cavanagh, Moloney, & Dao, 2011). The cognitive, behavioural and affective components of oral presentation competence should therefore all be included in the learning environment if we are to develop effective presentation curricula in higher education (Van Ginkel et al., 2015a).

A recent systematic literature review in this research field identified seven crucial educational design principles that foster students' oral presentation competence. Three of these seven principles refer directly to formative assessment strategies: expert feedback, peer assessment and self-assessment (Van Ginkel et al., 2015a). Although the effectiveness of these modes of feedback were explicated, a later experimental study demonstrated that students' presentation performance is influenced by the feedback source (Van Ginkel, Gulikers, Biemans, & Mulder, 2015b), and that feedback from teachers is preferred to feedback from peers, peers guided by tutors and self-evaluation. Moreover, a follow-up study demonstrated that teacher feedback scored better in higher education on feedback quality criteria than other common forms of feedback such as feedback from peers and peers guided by tutors (Van Ginkel, Gulikers, Biemans, & Mulder, 2016).

While feedback is regarded as a compelling influencing factor on students' learning (e.g. Attali & van der Kleij, 2017; Falchikov, 2005; Hattie & Timperley, 2007; Hung, 2016; Krause, Stark, & Mandl, 2009; Mayer & Moreno, 2002; Noroozi, Biemans, Weinberger, Mulder & Chizari, 2013; Noroozi, Weinberger, Biemans, Mulder & Chizari, 2013), the role of technology in practising presentations and facilitating high-quality feedback is scarcely mentioned in the 52 studies on presentation research analysed as part of the above-mentioned systematic literature review (Van Ginkel et al., 2015a). Only a few studies made use of technology, by videotaping students' individual presentations to facilitate self-assessment, which is believed to promote reflection skills and foster students' oral presentation competence. However, researchers argue that innovative technologies such as virtual reality-based tasks can help develop students' competencies, since interactive digital learning environments can imitate real-life processes and facilitate the provision of feedback (e.g. Coller & Scott, 2009; Lee & Wong, 2014; McNamara, Jackson, & Graesser, 2009; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014; Richards & Taylor, 2015). From a scientific perspective, it remains questionable whether a virtual reality-based presentation task for delivering feedback is as effective as a face-to-face presentation task with expert feedback (e.g. Chollet, Wörtwein, Morency, Shapiro, & Scherer, 2015; Lee, 1999; Merchant et al., 2014; Tanveer, Lin, & Hoque, 2015). Moving towards an educational practice perspective, however, such a research focus is essential since virtual reality technologies may help in the development of more effective and efficient learning environments. After all, increasing student numbers increases the pressure on higher education curricula, while instruction times and possibilities for teacher-student interactions decrease (Van Ginkel et al., 2015b). In recent years, computers have become more powerful, the costs of integrating virtual reality technology have decreased significantly and high-speed internet connections imply that a larger audience can be reached (e.g. Merchant et al., 2014). As such, virtual reality technology could be a solution to pressure on higher education curricula in the future if it could be (1) as effective as a face-to-face presentation task with expert feedback, (2) potentially more efficient in terms of reducing teaching staff time and costs, and (3) making individualised education (including personalised feedback) available for a large number of students.

The goals of this study were: (1) to investigate the impact of a virtual reality-based task, in which students present in a virtual environment and receive delayed feedback from the system, on students' cognition, behaviour and attitudes towards presenting and (2) to verify the extent to which students perceive such an innovative tool as valuable for practising presentations and receiving feedback for the development of their oral presentation competence.

2. Virtual reality: challenges and opportunities for higher education

This section focuses on the challenges and opportunities regarding the adoption of virtual reality-based tasks in higher education. Research results on the influence of virtual reality on learning outcomes are briefly summarised based on five review studies (Hew & Cheung, 2010; Lee, 1999; Merchant et al., 2014; Sitzmann, 2011; Vogel et al., 2006). These reviews were selected for this study because they: (1) directly relate virtual reality-based tasks to learning outcomes, and (2) are published in the context of higher education. Results from empirical studies on virtual reality, feedback and oral presentation competence, also published in other contexts, are discussed to formulate the hypotheses for this study.

2.1. Challenges to virtual reality in higher education

Resources (time and funding) are increasingly being deployed for the design and development of virtual reality-based instruction in higher education curricula (Merchant et al., 2014). This technology was first introduced in the entertainment sector in the 1960s (e.g. Hew & Cheung, 2010; Merchant et al., 2014), and 20 years later became increasingly popular in the professional education and training field, for example in preparing pilots for real-life flying tasks (Hawkins, 1995). Designers of virtual reality training sessions adopted various devices such as headphones, special glasses and powerful computers to immerse users in the full learning experience (e.g. Dubovi, Levy, & Dagan, 2017; Jang, Vitale, Jyung, & Black, 2017; Lorenzo, Lledó, Pomares, & Roig, 2016). However, studies

have also identified several concerns regarding the implementation of this technology in realistic higher education settings (Merchant et al., 2014). Reasons provided for the limited adoption of the technology in schools include lack of funding (Andolsek, 1995), negative perceptions from users regarding their psychological and physical state after experiencing virtual reality (Nichols & Patel, 2002), and the inferior technological design of virtual reality settings (Chen, Toh & Ismael, 2005; Riva, 2003).

2.2. Opportunities for virtual reality in higher education

Despite these earlier problems with the technology, several evolutionary factors have led to the adoption of virtual reality in education. Over the years, computers have become more powerful, the cost of integrating the technology in education has fallen significantly, and high-speed connections to the World Wide Web mean a larger user audience can be reached. However, the main reason why virtual reality-based technology is increasingly implemented in instruction is the potential it offers for enhancing students' competencies. Several educators have used these technologies to teach mathematical concepts (Pasqualotti & Freitas, 2002), theories in physics (Coller & Shernoff, 2009), and to develop 21st century skills, including research and communication skills (Galas & Ketelhut, 2006).

Virtual reality-based technology can be thought of as a system that uses displays, tracking, and other technologies to immerse the user in a virtual environment (LaViola, Kruijff, McMahan, Bowman, & Poupyrev, 2017, p. 8). However, for the purpose of this study, virtual reality environments are defined as interactive digital learning environments that imitate real-life processes or situations (Merchant et al., 2014). More specifically, the virtual reality system used in this study displays a virtual presentation space and tracks the presentation behaviour of the students to immerse them in the presentation environment (cf. LaViola et al., 2017). Further, the system delivers data that can be presented as feedback by the expert to the presenter. Such environments help students develop their learning processes and performances (De Jong, 1991). Moreover, virtual reality technologies make it possible to practice competencies needed in real-life, without contemporary educational restrictions on time or place, due to their portability and cost-effectiveness (e.g. Merchant et al., 2014; Tobias & Fletcher, 2010). It should, however, be noted that not all virtual reality systems are equally flexible when it comes to oral presentations (e.g. LaViola et al., 2017; Merchant et al., 2014), which may limit their portability. Depending on the competencies to be developed, certain virtual reality systems require dedicated rooms. This study required a virtual headset, a computer with certain specifications and software, connection cables and a presentation room. From the perspective of the teacher, this virtual reality system is to a certain extent portable within the higher education institution. However, the individual student is required to visit the presentation room on campus with the virtual reality system in order to rehearse a presentation. Since technologies are rapidly developing, new virtual reality technology is focusing on providing a virtual learning environment for the individual learner that can be used at a time and place that suits the user. As a result, the student would only need a smartphone, the presentation software App and a virtual headset.

2.3. Summary of previous reviews of virtual reality and impacts on learning outcomes

Previous meta-analyses published in the higher education context have revealed positive impacts of virtual reality-based technology on students' competencies (Sitzmann, 2011; Vogel et al., 2006). However, negative results have also been found, relating to students' perceptions of the adoption of this mode of technology for learning purposes (Lee, 1999). Other meta-analyses (Sitzmann, 2011; Vogel et al., 2006) have also reported several positive impacts on learning outcomes (self-efficacy, knowledge and retention), although a recently-conducted meta-analysis provided a more nuanced view of the influence of virtual reality-based learning environments on learning outcomes (Merchant et al., 2014). This research analysed 29 studies that incorporated a simulation tool in an experimental or quasi-experimental setting and revealed that they were effective in improving learning outcomes related to cognition, skills and attitudes. The authors also named certain design characteristics of virtual reality-based learning environments that can be considered more, less or equally effective in encouraging these components of competence. To start with, students appeared to learn more when virtual reality was implemented within a practice session rather than a situation in which the technology was used solely as a stand-alone configuration (Merchant et al., 2014; Sitzmann, 2011). Moreover, it was found that students performed significantly better when working on an individual task rather than a collaborative task. Results also revealed that the benefits of practising in a virtual environment do not depend on whether students receive feedback immediately after the performance or sometime later (Merchant et al., 2014, p. 36). The study (Merchant et al., 2014) also noted that publications on the impacts of virtual reality-based tasks combined with feedback modalities on the development of students' skills remain scarce. As previous literature has emphasised the tremendous impact of feedback on learning gains (Hattie & Timperley, 2007), the researchers recommended follow-up studies to investigate the impacts of virtual learning tasks combined with virtual feedback on the development of students' competencies in these specific, virtual environments (Merchant et al., 2014).

2.4. Summary of empirical studies on virtual reality, feedback and presentation competence

Although empirical studies of the impact of virtual reality on oral presentation competence development in the higher education context remain scarce, the adoption of virtual reality in clinical contexts is widely researched (e.g. Opris, Pintea, García-Palacios, Botella, Szamosközi, & David, 2012). However, the focus in this study is on oral presentation competence. More closely related are studies on virtual reality with the aim to reduce public speaking anxiety (e.g. Anderson, Zimand, Hodges, & Rothbaum, 2005; Harris, Kemmerling, & North, 2002; Pertaub, Slater, & Barker, 2001). These studies suggest that, when used to treat university students with public speaking anxiety, virtual audiences can be effective in reducing self-reported levels of anxiety. More specifically, Pertaub et al.

(2001) studied the effects of three different types of virtual audiences, namely a neutral, positive and negative audience, on public speaking anxiety. Results showed that the degree of anxiety experienced by the presenter was directly related to the type of virtual audience. A hostile, negative audience was found to have a strong effect on presenters in terms of their levels of public speaking anxiety (Pertaub et al., 2001).

In addition to empirical studies that aim to reduce speaking anxiety, other studies have demonstrated that oral presentation skills improve when presenting to a virtual audience (Batrinca, Stratou, Shapiro, Morency, & Scherer, 2013; Chollet et al., 2015; Tanveer et al., 2015). Innovative technologies such as virtual reality and augmented reality can be used to detect a speaker's volume and speech rate in real time and to provide feedback during the actual delivery of the presentation (Tanveer et al., 2015). Tanveer et al. (2015) reported that presenters evaluate a presentation experience accompanied by a sparse feedback strategy more positively than a situation with continuous or no feedback. Building on these studies, Chollet et al. (2015) explored immediate feedback strategies for public speaking training based on an interactive virtual audience. In this experiment, presentation performance was monitored in terms of presentation delivery aspects such as eye contact, posture and gestures. Direct feedback could be provided using a colour-coded gauge positioned above the audience, or the virtual audience could respond positively or negatively to the presenter's performance. The results show that an interactive virtual audience significantly increases oral presentation performance as assessed by presentation experts (Chollet et al., 2015).

In summary, it can be stated that:

1. Virtual reality-based tasks have largely been researched in the clinical or computer science context (Opris et al., 2012). However, this study on a virtual reality-based presentation task for delivering feedback is conducted in realistic presentation skills courses in the higher education context to ensure the ecological validity of the study.
2. Previous studies on virtual reality in presentation research have focused on reducing public speaking anxiety or developing presentation skills. However, other components such as 'cognition towards presenting' and 'attitudes towards presenting' need to be included in experimental studies, since these components are highly interrelated within the 'construct of competence' (Mulder, 2014).
3. Although previous studies on feedback modalities in virtual reality have focused on providing immediate feedback on presentation delivery aspects, delayed feedback provided verbally by an expert can also be considered an essential type of feedback for developing oral presentation competence in higher education (Van Ginkel et al., 2016).
4. Most studies on virtual reality in the context of developing presentation skills focus on feedback modalities that are provided within the virtual reality system. However, it remains questionable whether feedback based on the virtual reality system is as effective as common feedback sources such as presentation experts providing delayed feedback based on their own observations (Van Ginkel et al., 2015b).
5. Although students' perceptions of the value of feedback in virtual reality systems have been researched (e.g. Tanveer et al., 2015), it is unclear whether students evaluate feedback based on the virtual reality system as equal to feedback from a presentation expert based on observation of a face-to-face presentation task.

2.5. Rationale for this study

Previous studies have revealed positive effects of virtual reality-based tasks for fostering students' competencies (e.g. Merchant et al., 2014; Sitzmann, 2011; Vogel et al., 2006). More specifically, positive results were found in several studies in the clinical and computer sciences contexts that focused on virtual reality-based tasks for delivering feedback on students' communication or presentation performances (e.g. Batrinca et al., 2013; Chollet et al., 2015). However, traditional forms of expert feedback have also proven to be highly effective in higher education (Van Ginkel et al., 2015b, 2016). For example, a quasi-experimental study of presentation skills courses among 144 first-year undergraduate students showed that feedback from teachers (experts) outperformed feedback from peers, peers guided by tutors, and self-evaluation (Van Ginkel et al., 2015b). Furthermore, a follow-up study revealed that teacher feedback scored higher on feedback quality criteria than other common feedback sources (Van Ginkel et al., 2016). Based on these insights from the literature, the purpose of this study is to explore whether a virtual reality-based presentation task with feedback generated by the computer and explained by an expert has a similar impact on developing students' oral presentation competence as a face-to-face presentation task with expert feedback. In order words, we wanted to verify whether the virtual reality condition was at least as effective as the normal condition in terms of impact on students' oral presentation competence, because the regular (control) condition already has a very high level of quality but is hardly sustainable in the near future (see Van Ginkel et al., 2015b). The strength of the control condition is reflected by the student evaluations of the previously adopted oral presentation skills courses. Every academic year these presentation skills courses belong to the most highly evaluated courses of the university (Van Ginkel et al., 2015b). However, since student numbers are rising while instructional time and possibilities for teacher-student interactions are diminishing (e.g. De Grez, Valcke, & Roozen, 2009; Van Ginkel et al., 2015b), considering other options is essential. This is relevant for higher education institutions since the use of virtual reality is potentially more efficient but should be just as effective as traditional methods for teaching and learning oral presentation skills. The traditional method referred to here consists of a face-to-face presentation in a regular classroom setting with feedback provided by the presentation expert. Students then reflect on their own performance by watching video recordings of their presentation. As such, this study was designed as an experimental field study, the aim of which was to demonstrate that virtual reality is a promising technology for developing oral presentation competence. As a result, the hypotheses are described as follows:

1. The effect of the virtual reality-based task on students' knowledge of the core aspects of oral presentations is equal to that of the face-to-face task.
2. The effect of the virtual reality-based task on students' oral presentation skills is equal to that of the face-to-face task.
3. The effect of the virtual reality-based task on students' attitude towards giving oral presentations is equal to that of the face-to-face task.
4. Students' evaluations of the characteristics of the virtual reality-based task are equally positive as students' evaluations of the characteristics of the face-to-face task.

3. Method

3.1. Study participants and context

The experiment was carried out in the life sciences department at a Dutch research university. In the autumn of 2016, 36 Dutch first-year undergraduate students followed an obligatory oral presentation course. The majority of participants (69%) were male, while 31% were female. The aim of the course was for students to acquire skills in public speaking. More specifically, the course offered students the opportunity to discover and practice the skills that are necessary to deliver an authentic and persuasive presentation in an academic context. This course was designed based on the crucial components for constructing effective and efficient learning environments to foster presentation competence, as previously addressed in a systematic review study (Van Ginkel et al., 2015a). First of all, regarding the 'instruction' component, all students were required (1) to formulate learning objectives regarding their own oral presentation competence, and (2) to individually conduct two five-minute presentations during the course. Secondly, relating to the 'learning activities' component, students were required (3) to observe presentation models of peers and experts, and (4) to practice their presentation skills in individual and group tasks. Finally, considering the 'assessment strategy' component, students were (5) guided in providing feedback formulated in a constructive manner, (6) involved as peers in offering and receiving feedback, and (7) encouraged to learn from self-assessment and reflection by watching their own presentation behaviours on video. All seven of these essential strategies for developing oral presentation competence were addressed in the presentation skills course. However, only strategies four and five (the opportunity to practice presenting and providing feedback) were manipulated in this experiment.

The study (see Fig. 1) consisted of three sessions, with a week between each session. The first session was a plenary meeting and used to construct individual learning objectives, to learn from observing presentation behaviour and to develop feedback skills. In the second session, students gave their first individual presentation of five minutes on a self-selected topic to a group of seven or eight students. This session was facilitated by a teacher. Finally, in the third session, students gave their second presentation, again of five minutes on a self-selected topic. Students were expected to make the most progress in the phase between the first and second presentation (Calcich & Weilbaker, 1992). Students selected their own topic within their own specific discipline in the life sciences as this is also the case in regular presentation courses at the same university, and therefore guarantees the ecological validity of this study. It was also felt that this would help increase the students' motivation: research has shown that students who present a topic that is closer to their interests score significantly higher on oral presentation competence than students who present on a topic of less interest to them (De Grez et al., 2009).

After the second session, and a couple of days before the third session, students in the experimental group practiced their presentation in a virtual reality environment and received feedback from an expert (i.e. an experienced teacher) on three presentation delivery aspects registered by the computer system (use of voice, eye contact, and posture and gestures). The control group consisted of students who practiced their presentation face-to-face with an expert and also received feedback on the same presentation delivery aspects as the experimental group. However, the control group were not supported by digital data registered by a computer system. Previous research has shown that the expert (i.e. an experienced teacher) is the most effective feedback source commonly used in higher education practice for fostering presentation performance (Van Ginkel et al., 2015b). Six presentation experts were involved in this study. This number of experts was needed to run all of the two times six parallel smaller group sessions (pre-test and post-test). Both pre-tests and post-tests were carried out during these sessions, as all presentations were assessed by the presentation experts immediately after the presentation. To achieve standardisation of the procedure and to ensure an acceptable interrater reliability for performance measures (Cohen's Kappa = .73), the same experts were used as in an earlier quasi-experiment among 144 first-year undergraduate students in the academic year 2013–2014. This previous study had focused on the potential differential impact of the feedback source on the development of students' oral presentation competence (Van Ginkel et al., 2015b, 2016).

3.2. Ethical considerations within this study

In order to guarantee the integrity of the experiment, several actions were taken. First of all, we adopted the guidelines for research integrity, which were expressed in the Netherlands Code of Conduct for Scientific Practice. This code states that integrity in designing and carrying out research projects needs to be ensured. Further, research should protect human participants from any possible harm. Second, prior to the experiment, approval was asked and received from the responsible Program Director of the BSc programme 'International Land and Water Management' in which the oral presentation course was integrated. The presentation course was an official and mandatory part in the students BSc curriculum. All students had to take this course and were informed beforehand of the course objectives that they had to learn to present and had to provide presentations individually. The presentation part consisted of 40% of the end mark of the course. All this information was specified in the course guide. Third, permission was

PHASE	ITEMS	DESCRIPTION	TIME
WEEK 1	**Session 1**	**The plenary meeting**	150 minutes
	Number of students	40 students	
	Measurements of cognition and attitude	Multiple choice test (pre-test) and self-evaluation questionnaire (pre-test)	10 minutes
	Learning environment characteristics	Objectives, Modelling, Feedback	150 minutes
WEEK 2	**Session 2**	**First smaller group sessions**	150 minutes
	Number of students	40 students (in total)	
	Measurements of presentation skills	Oral presentation skills rubric (pre-test)	40 minutes
	Presentation task	Presentation of five minutes on a self-selected topic	40 minutes
	Learning environment characteristics	Objectives, Modelling, Practice, Feedback, Peer assessment, Self-assessment	150 minutes
MID-WEEK 2	**Instructional conditions**	**Virtual reality (VR) or control condition**	30 minutes for each individual presentation
	Instructions to all experts	Regarding presentations and feedback; Availability of oral presentation skills rubric	45 minutes in total for each presentation expert
	Instructions to experts depending on condition	Environment of the presentation task (VR or control); The adoption of feedback reports (VR only)	45 minutes in total for each presentation expert
	Number of students	36 students (17 in VR; 19 in control condition). Ill students (3 in VR; 1 in control)	
	Presentation task	Presentation of five minutes on a self-selected topic	180 minutes
	Learning environment characteristics	Practice, Feedback	30 minutes for each individual presentation
WEEK 3	**Session 3**	**Second smaller group sessions**	150 minutes
	Number of students	34 students (in total) present during the presentations	
	Measurements of presentation skills	Oral presentation skills rubric (post-test)	40 minutes
	Presentation task	Presentation of five minutes on a self-selected topic (N=34)	40 minutes
	Measurements of cognition and attitude	Multiple choice test (post-test) and self-evaluation questionnaire (post-test) (N=36)	10 minutes
	Evaluation test	Evaluation questionnaire (post-test) (N=36)	15 minutes
	Learning environment characteristics	Objectives, Modelling, Practice, Feedback, Peer assessment, Self-assessment	150 minutes

Fig. 1. Overview of the experimental study procedure.

asked and approved by the specific Course Coordinator and Teachers who organised and provided this course. Within this university, this procedure is considered as institutional approval that is needed for conducting experimental studies. Fourth, all students were informed prior to the research and were asked whether they wanted to participate in the experiment or choose the regular presentation format. Thus, students could individually decide to opt out of the experimental condition, and follow the regular course on oral presentation skills if they wanted. Further, they were informed that their choice to participate in the experiment or not would have no consequences on their grade. However, students had no objections against this experiment, and agreed with the randomized assignment to the experimental or control condition. The students who were absent due to sickness reported that this was in no way attributable to the research being undertaken. Thus, all relevant parties provided informed consent. Fifth, students' personal details were omitted from the data analysis. In line with this, the data management protocol of the Chair Group, which is endorsed by the Social Sciences Group, and mandatory within the university, was followed. This procedure is similar to other previous research with comparable designs (f.e. Noroozi, Biemans, & Mulder, 2016; Van Ginkel et al., 2015b). Finally, in order to check for other considerations regarding ethical issues, the presentation skills course was evaluated amongst students in the same way as other courses within this university. This resulted in no reports of any dissatisfaction with the research procedure.
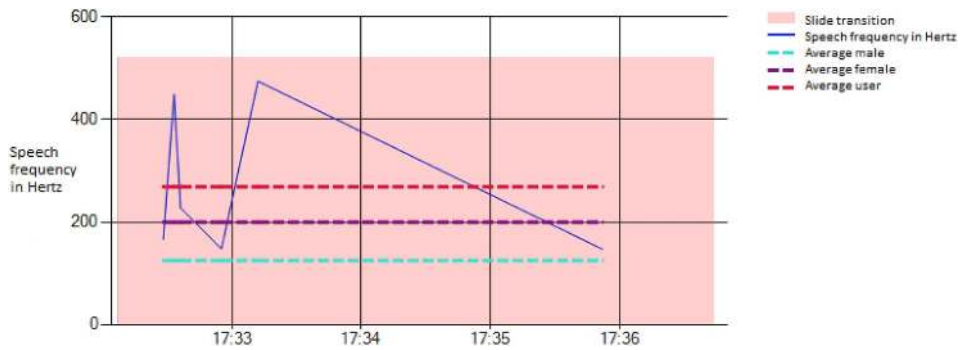
Fig. 2. Speech frequency in Hertz.

3.3. Instructional conditions

The participants in this experiment were randomly assigned to one of the following feedback groups: (1) the virtual reality-based task (n = 17) or (2) the control condition (n = 19). In the virtual reality condition, 13 students were male and 4 students were female. The control condition consisted of 12 male students and 7 female students. The experimental condition consisted of a five-minute individual presentation on a self-selected topic to a virtual audience in a virtual presentation room using a virtual reality headset and an additional headphone (see design principle 4 in Van Ginkel et al., 2015a; see also Section 3.4). After the presentation, the student received feedback on presentation delivery aspects registered by the computer system (i.e. use of voice, eye contact, and posture and gestures) from an external feedback source (the expert, i.e. an experienced teacher). This task was designed in the virtual reality system based on design principle 5 regarding the type of feedback (see Van Ginkel et al., 2015a). The expert was needed in this condition to interpret the information from the feedback reports and explain this to the presenter. This feedback session lasted five minutes. Examples of a computer-generated feedback report are given in Figs. 2 and 3. The first graph shows the speech frequency, measured in hertz (Hz) during the presentation performance, which can be considered an essential aspect of presentation delivery for holding the audience's attention (see Fig. 2). The second graph shows the speech rate in words per minute, which may influence the ability of people in the audience to understand the presentation (see Fig. 3). Such reported aspects can provide a detailed analysis of the presenter's performance with respect to specific presentation delivery aspects. This essentially constitutes quantified information on students' actual performance (e.g. Hattie & Timperley, 2007; Van Ginkel et al., 2016).

The control group also gave an individual face-to-face presentation of five minutes on a self-selected topic to an expert. Directly after, the presenter received five minutes of feedback on presentation delivery aspects as observed and explained by the expert based on the 'oral presentation skills' rubric (see Fig. 4). At the time of the experiment, all the experts involved in this study had more than five years of experience in providing public speaking courses at the level of higher education or professional training. The experts were individually briefed by the course leader of the presentation skills course and the first author prior to the intervention. In these briefing sessions, the experts received identical instructions on how to facilitate the feedback processes in both conditions. This included: (1) the procedure for the presenter with instructions on presentation performance and receiving feedback, (2) instructions to clock and restrict feedback to five minutes to guarantee comparable feedback times in both conditions and (3) an 'oral presentation skills' rubric for each expert to guide the delivery of feedback after the presentation in relation to the three previously-mentioned presentation delivery aspects (Van Ginkel et al., 2017). Rubrics have been shown in previous studies in the field of higher education to improve feedback processes that aim to enhance learning outcomes (e.g. Jonsson & Svingby, 2007; Panadero & Jonsson, 2013; Prins, De Kleijn, & Van Tartwijk, 2015, pp. 1–23). In addition to the identical instructions for facilitating the feedback process, the experts were provided with specific guidelines for the particular condition regarding: (1) the presentation practice task environment
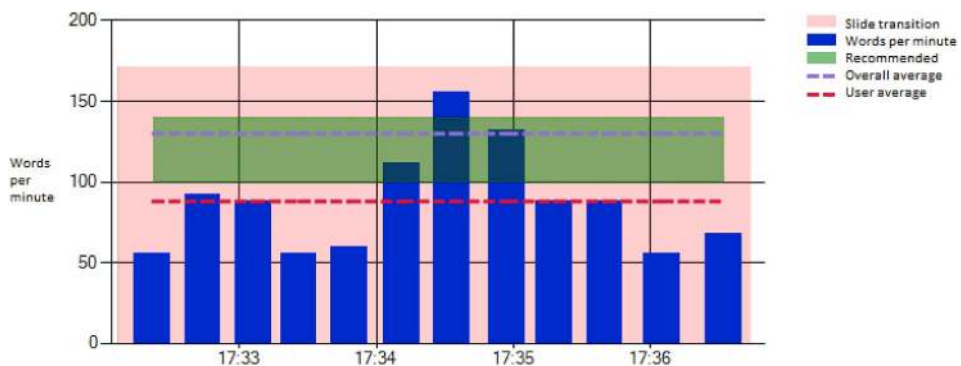

Fig. 3. Speech rate in words per minute.

	++ (10)	+ (8)	+/- (6)	- (4)	-- (2)	Score
Posture and gestures	The student is able to maintain an open posture continuously with illustrative gestures.	The student is able to maintain an open posture for most of the time with supporting gestures.	The student is able to maintain an open posture on a regular basis, both with supporting and non-supporting gestures.	The student is able to maintain an open posture occasionally with mainly non-supporting gestures.	The student has an unstable or closed posture for most of the time with non-supporting gestures.	

Fig. 4. An example of a sub-criterion in the oral presentation skills rubric.

(the virtual reality environment or face-to-face with an expert), and (2) the computer-generated feedback report supporting the delivery of feedback by the expert (only available in the experimental group).

In both conditions, there was no real audience as the learning task was to rehearse a presentation individually, so without fellow students or any other live audience. This mirrors the authentic situation of rehearsing presentations individually. To strengthen the comparability of the two conditions, an expert was present to manage the experiment and to give feedback on the presentation. As the students in the virtual reality setting presented in front of a virtual audience and the students in the control condition in front of an expert, conclusions from research into the potential impact of group size on speaking anxiety are relevant. Research by McKinney, Gatchel, and Paulus (2010), for instance, showed that situational factors such as group size can affect speech anxiety, and that high speech-anxious subjects prefer to speak publicly in small groups. However, these authors did not find any physiological differences between low and high speech-anxious subjects when speaking to no, two or six persons. Other research (Ayres, 2009) contests the influence of situational variation and states that predispositions are more important. This is corroborated by research by Beatty and Friedland (2009), which showed that trait versions of variables explained more variation in speech anxiety than situational versions of variables. Thus, predispositional variables may have stronger effects than situational variables. In any case, it is assumed that speech anxiety is modest in this target group and that, if it is present, it is proportionally distributed across both conditions. This means that speech anxiety does not systematically harm the internal validity of our design, nor does it lead to spurious study effects. Further, the adoption of experts in audiences and feedback procedures is previously emphasized by researchers as crucial for having a positive or negative impact on speech anxiety or presentation skills (e.g. Haber & Lingard, 2001). Contextual feedback is crucial to prevent dysfunctional generalizations by students, resulting in deficient presentation skills (e.g. Haber & Lingard, 2001; Kim, Kogan, Bellini, & Shea, 2005). However, these examples are specifically framed within medical education, in which students present in front of audiences of content-experts, which is likely to result in high levels of speech anxiety (Van Ginkel et al., 2015a). This experimental study, however, is not situated in the medical context, in which speech anxiety and deficient presentation skills could have serious possible negative consequences for patients, clients or the professional development of peers. Since the presentation skills courses were aimed to develop students' oral presentation skills (such as eye contact, use of voice and posture and gestures) in various domains within the university, process-experts and non-content experts, were used in these courses and this experimental study in particular. Therefore, these audience members would not have such an impact on students' speech anxiety in comparison to content-related experts.

3.4. The virtual reality condition

3.4.1. The virtual experience

The student entered the experimental condition classroom alone and was welcomed by the presentation expert (or trainer). The same procedure was followed in the control condition. The role of the presentation expert in the virtual reality condition included: (1) instructing the student about the procedure of giving an oral presentation of five minutes using the virtual reality device, (2) providing feedback, restricted to five minutes, based on feedback reports produced by the virtual reality system, and (3) directly relating the content of the feedback report to presentation delivery aspects (such as eye contact, use of voice, posture and gestures). This procedure is also described in the validated 'oral presentation skills' rubric (Van Ginkel et al., 2015b). Before giving the presentation in virtual reality, the student received five minutes of instruction from the presentation expert on what s/he would experience in the virtual reality environment. After instruction, each student in the experimental condition was handed the virtual reality headset and asked to put it on. As the same experimental condition was conducted in two parallel classrooms, two identical setups were used in this experiment. This setup consisted of (1) a headset with combined headphone and microphone to record the presenter's use of voice and the virtual reality headset to track eye contact (the HTC VIVE was used as the virtual reality HMD, in room scale experience mode), (2) a computer component to register the presenter's movements (Microsoft Kinect Windows version 2 was used), and (3) a gaming PC to run the virtual reality software and obtain virtual reality measurements (the main specifications were 16 GB RAM, NVIDIA 1080 GTX, Intel i7-6700K 4.00Ghz). Through the headphones, the student could hear coughing in the audience during the presentation and applause from the audience at the end. The virtual audience consisted of 100 avatars sitting in chairs, able to move as a normal audience would do. The presenter's voice was recorded through the microphone. Since this microphone was part of the headset, an equal microphone to mouth distance was ensured in both parallel classrooms in the experimental condition to support comparable measurements. Before conducting the actual presentation, the presentation expert checked that the headset was positioned correctly and that the student was receiving visuals and audio. This check was carried out to ensure the user experience in the virtual room was fully immersive. The only response the student received at this point was the virtual avatar crowd mumbling before the presentation. Finally, before giving the presentation, the student checked on a virtual small screen in front and on the large presentation screen behind her/him to see whether the PowerPoint slides had been uploaded in the virtual reality system. The student used a remote control (VIVE controller) in one of her/his physical hands to control these slides. After the

presentation, the student removed the headset and took a couple of seconds to acclimate to the physical space around them. During this period, the report was generated and opened by the presentation expert to provide feedback, which was restricted to five minutes. The expert interpreted the report data according to the validated 'oral presentation skills' rubric (Van Ginkel et al., 2015b) and explained the outcomes to each individual student in the experimental condition.

3.4.2. The virtual reality presentation and audience response

When the student started the presentation, the audience stopped mumbling and looked in the direction of the user. Since the virtual presentation was given in a first-person view experience, the student was standing in front of the audience rather than seeing her- or himself. This virtual audience was programmed to minimally respond to two types of non-verbal behaviour. The first type of non-verbal behaviour was 'eye contact'. The virtual reality application determined whether the presenter was making eye contact with the virtual audience and the virtual reality headset measured the direction in which the presenter looked and for what length of time. For example, if the presenter looked at the slides behind her/him on the large virtual screen for more than 20 seconds, the audience started to mumble again and show restless behaviour by moving their arms and turning their heads away from the presenter (e.g. De Grez, 2009; Kang, 2016; Schneider, Börner, Van Rosmalen, & Specht, 2015; Van Ginkel el al., 2015a). When the user started to make eye contact again, the avatars in the audience would reengage with the presenter. The second type of non-verbal behaviour was 'voice volume', registered using the microphone. If the volume of the presenter's voice fell below 30 decibels (dB), the audience again started to get restless (e.g. De Grez, 2009; Kang, 2016; Schneider et al., 2015; Van Ginkel el al., 2015a). However, the audience was not able to talk or ask the presenter questions. The presentation experts in both the experimental and the control condition were instructed on these non-verbal behaviours, to provide the presenter with the same type and level of non-verbal behaviour.

3.4.3. The virtual reality technology

Virtual reality software was created using two software components to optimise the user experience and to measure presentation delivery aspects (as described above). The first of these components, the user interaction module, was developed in the game engine 'Unity' (e.g. Unity Technologies, 2014). This software component included (1) user interaction (e.g. starting the presentation by clicking forwards and backwards through the PowerPoint slides using the VIVE controller), (2) visualisation (e.g. user standing in a 3D room with chairs, projector screens showing the PowerPoint slides and 3D models of avatars in the audience that can move based on constructions with Mixamo, 2018), and (3) main algorithms (e.g. detection of the user's view direction using raycasting, a randomiser for letting random audience members cough, and the integration of active MQ for communication of measurement data to C#). The second component was a measurement module developed in programme C# to (1) measure user interaction (e.g. to open the generated feedback report in Word after the presentation, including duration in time, percentage of speech time, intonation graph in Hz, volume graph in dB, and words per minute and posture/gestures graphs all plotted against time), (2) integrate Microsoft Kinect to detect user movements, the microphone module to record audio from the user, the connection to Google Speech (v1beta1) to convert audio into text, a Word export module to export the reports with the graphs and an ActiveMQ module for communicating data with Unity, (3) implement main algorithms to count words from speech-to-text output, analyse the audio bytes to obtain the pitch in Hz, register the volume from the recorded audio and convert the 3D scan information from Kinect into postures and gestures (e.g. arms crossed, hands folded, hands in pockets, hands in side, hands on back and hands touching the head), and (4) calculate the focus level of the audience (e.g. the audience was the most focused when maximum points were scored, such as 10 points for a volume between 30 dB and 90 dB and 10 points for looking at the audience for more than 70% of the time).

3.5. Dependent variables and instruments

Students' cognition, behaviour and attitudes towards presenting were tested in a pre- and a post-test situation. Students' perceptions of the value of the course, the task for practising their presentation (either in a virtual or face-to-face environment), and the received feedback (with or without the digital feedback data registered by the computer system) were then traced using an evaluation questionnaire (post-test only) after the last presentation.

3.5.1. Cognition towards presenting

Cognition towards presenting is defined as students' knowledge of the main criteria for presentations (the content and structure of a presentation, the interaction with the audience and presentation delivery aspects). Students' presentation knowledge was measured using two multiple-choice tests. The first of these was completed at the start of the first plenary session of the course (pre-test) and the second following the second presentation (post-test). These tests contained six questions directly related to the core criteria for delivering presentations as obtained from the literature (Van Ginkel et al., 2015a, 2015b). An example of a question in the multiple-choice test that measures cognition towards presenting is 'Which three elements are essential in the introduction of a presentation?'. Scores were determined by summing the correct answers. Adequate reliability coefficients for this instrument were reported for both pre-test and post-test (Cronbach alpha = .78 and .77 respectively).

3.5.2. Presentation behaviour

Presentation behaviour was assessed based on a previously validated 'oral presentation skills' rubric (Van Ginkel et al., 2015b). This rubric consisted of (1) 11 sub-criteria belonging to the main criteria for delivering oral presentations, (2) presentation performance levels, and (3) qualitative descriptions of these presentation behaviours. An example of how one sub-criterion was formulated in the rubric is shown in Fig. 4 (see also Van Ginkel et al., 2015b). The students' presentation skills were evaluated by the

teacher responsible for guiding the feedback processes during the presentation in the smaller groups in the second and third meetings of the course. These teachers received training in how to use the rubric instrument during one plenary meeting and individual coaching sessions prior to the experiment. The performance assessments were conducted by the same person in the pre- and post-tests. Scores were obtained by calculating the average grade for each of the 11 sub-criteria. As the feedback in both conditions focused on presentation delivery aspects, a score was also obtained for the students' presentation performance for these aspects (use of voice, eye contact and posture and gestures). The reliability coefficient revealed a high score (ICC = 0.75), which was in accordance with a previous experiment (Van Ginkel et al., 2015b).

3.5.3. Attitude towards presenting

The students' change in attitudes to presenting was tested through the self-evaluation of students' perceptions regarding the effort required, motivation for and relevance of giving a presentation (Van Ginkel et al., 2015b). These tests consisted of five propositions scored on a five-point scale. One assessment was completed in the first plenary session (pre-test) and the other after the second presentation (post-test). An example of an item in the self-evaluation test was 'I consider presenting to be a relevant skill in the context of my study'. Scores were calculated by taking the average of the five test items. As in a previous study (Van Ginkel et al., 2015a), an adequate score was reflected in the reliability coefficient (Cronbach alpha = .77).

Finally, an evaluation questionnaire (post-test only) was completed by all students after the second presentation. This included seven closed questions on a five-point scale and four open questions. Three closed questions concerned generic issues relating to the relevance of the presentation skills course for (1) developing presentation skills, (2) motivating students to develop presentation skills, and (3) receiving useful feedback on presentation performances. The other four closed questions related to perceptions of specific characteristics of the described feedback conditions, namely (4) the extent to which students perceive the presentation task to provide realistic preparation for their final presentation, (5) whether the presentation task motivates students to practice a presentation, (6) the value of the received feedback after the presentation task, and (7) the recommendation to other students to carry out the presentation task in a virtual environment or face-to-face. The open questions concerned (1) the aspects of non-verbal communication on which students received feedback from the expert, (2) whether they missed any feedback, (3) to what extent they perceived the presentation task as valuable for improving their oral presentation competence, and (4) whether students from the experimental group thought the virtual reality task could replace face-to-face presentations in educational practice.

3.6. Data analysis

A repeated measures MANOVA was carried out to examine the effect of the two instructional conditions over time (students' progress between the pre-test and post-test), the effect of the condition (virtual reality versus expert feedback) and the interaction between the condition and time. The three foci were cognition towards presenting, presentation behaviour and attitudes towards presenting. A two one-sided test procedure (TOST) was also applied (Lakens, 2017; Wuensch, 2014) to analyse the equality of the effect of the conditions on students' presentation competence, using the SPSS script by Wuensch (2012).

The dimensionality of the closed questions in the student evaluation was evaluated using principal component analysis (PCA). The number of principal components extracted was determined based on the scree plot, the eigenvalues and the proportion of variance explained by the principal components. An oblique rotation was used to allow for correlations between the factors, after which it was decided whether to use an oblique or an orthogonal rotation based on the size of the correlations. The TOST procedure was then adopted to examine the equivalence of the conditions. The power of the MANOVA and the t-tests were examined using power analyses carried out in G*POWER 3. All analyses were run in IBM SPSS version 25 as this programme has practical built-in functions for repeated measures MANOVA.

Finally, the answers to the open questions were collected and categorised using the inductive thematic analytical technique (e.g. Braun & Clarke, 2006; Clarke & Braun, 2013; Hayes, 2000), as recently applied in comparable studies that focused on the development of competencies in the higher education context (i.e. Popov et al., 2014). This data was interpreted based on descriptive statistics and contingency tables.

4. Results

In this section, we start by describing the sample, followed by the power analysis for the different effects of the MANOVA for the oral presentation competence variables. We then present an overview of the MANOVA results. We also present the TOST results for the oral presentation competence variables: cognition towards presenting, presentation behaviour and attitudes towards presenting. An overview of the PCA results for the evaluation items is also provided, as well as the TOST results based on the evaluation factors. Finally, the data relating to the open questions is presented and discussed.

4.1. Sample

The sample consists of 36 subjects: 17 in the virtual reality condition and 19 in the face-to-face condition. Two subjects had missing values on the skills items in the 'oral presentation competence' rubric. However, the small sample size meant that removing these subjects from the samples would reduce the power of the statistical tests. Mean imputation was therefore used to deal with these missing values.

Table 1
Univariate results of the repeated measures MANOVA.

Variable	Condition	VR			Control			F	df	p
		Mean t1 (sd)	Mean t2 (sd)	n	Mean t1 (sd)	Mean t2 (sd)	n			
Cognition		4.41 (1.00)	5.65 (0.61)	17	4.16 (0.76)	5.42 (0.77)	19			
	Time							49.15	1	< .001*
	Condition							1.48	1	.233
	Condition*time							0.01	1	.938
Skills		7.18 (0.83)	7.97 (0.73)	17	7.12 (0.48)	7.85 (0.37)	19			
	Time							70.18	1	< .001*
	Condition							0.26	1	.612
	Condition*time							0.12	1	.732
Attitude		3.68 (0.61)	3.87 (0.60)	17	3.65 (0.65)	3.86 (0.66)	19			
	Time							9.06	1	.005*
	Condition							0.01	1	.927
	Condition*time							0.03	1	.867

*Significant at $\alpha = 0.5$.

4.2. Students' progress in presentation components

Power analysis was first carried out for small effects. This showed that the MANOVA was underpowered for between-subjects effects and between-within interactions, with relative powers of 31% and 25% for the detection of small effects ($\eta^2 = 0.05$). The power for small within effects was larger, around 58%. This can be interpreted as low power, which will likely also affect the equivalence test results. To deal with this, effect sizes were reported for all results.

Before conducting MANOVA, the assumptions needed to be verified. First of all, the dependent variables were all measured at the interval or ratio level and all dependent variables except for the cognition variable at the post-test were normally distributed. However, as MANOVA is quite robust to violation of the normality assumption, MANOVA was preferred over non-parametric options. Furthermore, a scatterplot of the dependent variables indicated that all dependent variables were approximately linearly related. The homogeneity of variances was tested using the Box's test of equality of covariance matrices, and turned out to not be significant ($p = .119$). No multicollinearity should therefore exist.

An overview of the MANOVA results is given in Table 1. For the multivariate test, only time was significant ($p < .001$), with a large effect, $\eta^2 = 0.71$. Students therefore scored higher on the oral presentation competence variables in the post-test compared with the pre-test. The effect of condition in this sample was non-significant ($p = .708$) and small ($\eta^2 = 0.04$). Furthermore, the interaction between condition and time was non-significant ($p = .969$) and trivial ($\eta^2 = 0.01$). In this sample, the condition did not differ over time. This pattern was also shown in the univariate statistics, since none of the univariate between-subjects comparisons of the conditions were significant, with effect sizes η^2 between < 0.01 and 0.03. However, time was significant for all dependent variables, with effect sizes of $\eta^2 = 0.59$ for knowledge, $\eta^2 = 0.64$ for behaviour and $\eta^2 = 0.21$ for attitudes. The interaction between time and condition was non-significant for all dependent variables, with all effect sizes characterised as $\eta^2 < 0.01$. The interaction plots for all oral presentation competence variables are shown in Figs. 5, 6 and 7 (see appendices).

In order to test whether the two methods performed equally, the TOST test for non-inferiority was applied (Lakens, 2017; Wuensch, 2014). The confidence intervals were quite wide, with a Cohen's *d* CI of −0.54 to 0.77 (estimate = 0.11) for behaviour, −0.60 to 0.71 for attitude (estimate = 0.06) and −0.63 to 0.68 (estimate = 0.03) for cognition. These intervals were all wide and far outside the interval for non-inferiority, which was set at −0.10 to 0.10.

4.3. Students' perceptions of presentation tasks for delivering feedback

PCA was carried out to examine the dimensionality of the questions in the student evaluation. First, the assumptions of the PCA were tested. The minimum sample size required is approximately five subjects per variable. Taking this into consideration, 36 subjects for 7 questions was just above the threshold of 35 subjects for 7 questions. The Kaiser-Meyer-Olkin measure of sampling

Table 2
Correlations, means and standard deviations of the evaluation questions.

Question	1	2	3	4	5	6	7	Mean (sd)
1. Course valuable	–							4.61 (0.55)
2. Course motivating	.04	–						4.25 (0.65)
3. Feedback useful	.22	.07	–					4.56 (0.65)
4. Task realistic	.06	.21	.01	–				3.39 (1.34)
5. Task motivating	.16	.19	.17	.39	–			3.86 (0.99)
6. Feedback valuable	.28	.25	.57	.39	.63	–		4.25 (0.84)
7. Recom-mend task	-.13	.36	.08	.67	.55	.56	–	4.11 (0.98)

Table 3

Eigenvalues, % variance explained, cumulative % variance explained.

Factor	Eigenvalue	% of variance	Cumulative % variance
1	2.88	41.14	41.14
2	1.42	20.24	61.37
3	0.86	12.32	73.69
4	0.84	12.00	85.68
5	0.59	8.38	94.07
6	0.24	3.43	97.50
7	0.18	2.50	100.00

adequacy, which was 0.621, indicated that the sample was large enough (KMO > 0.5). Furthermore, the factors should be somewhat correlated. The correlations in Table 2 show that all items have moderate correlations with at least one other item. Bartlett's test of sphericity, used to indicate the adequacy of the correlations, was significant ($p < .001$), suggesting that the variables were correlated adequately. The variables should also have approximately linear relations, a matrix scatterplot of all the variables showed no non-linear patterns between the variables. Finally, the PCA requires no strong outliers on the variables. Boxplots of the variables showed some outliers in the data but, as the number of subjects was quite low, all the subjects were kept in the dataset. This does mean that the factor solution might not be optimal and should not be generalised outside the sample.

Table 3 shows the eigenvalues and explained variance of principal components 1 to 7, and Fig. 8 (see appendices) shows the scree plot of the factors. Based on this information, the most adequate choice for the number of components was two or three. More specifically, the slope between the second and third component was decidedly less steep than the slope between the first and second component, although it was still relatively steep. The real elbow in the scree plot appeared more clearly after the third component. Furthermore, the eigenvalues criterion would indicate a solution with two components, but this is a somewhat arbitrary criterion. Finally, the amount of explained variance criterion suggested a three-factor solution, with two factors explaining 61.37% of the total variance and three factors explaining 73.69% of the variance. Based on the criteria, a three-factor solution was chosen.

The factors task value and informativeness were correlated with r = 0.15. The factors task value and motivation were correlated with r = 0.27. Finally, the correlation between the factors informativeness and motivation was almost non-existent at r = 0.03. However, the correlations were considered too high to use an orthogonal rotation and an oblique rotation method was favoured instead. The rotated factor solution is shown in Table 4.

To examine the interpretations of the factors, the items associated with each factor were considered. The first factor includes four items: (1) whether students would recommend that other students carry out the presentation task using virtual reality or face-to-face feedback, (2) whether the presentation task provided realistic preparation for the final presentation, (3) whether the task was motivating in terms of practising a presentation, and (4) to what extent the feedback received after the task was considered valuable. The second factor contains the following items: (1) to what extent the feedback received after the task was considered valuable, (2) whether the feedback received was useful, and (3) whether students found the total course valuable. The third factor consists of a single item, (1) whether the course as a whole was motivating. Factor one can be said to concern the student's perception of the value of the virtual reality or face-to-face task itself ('task value'). The second factor describes the extent to which students perceived the feedback and course as informative ('informativeness'). The final factor describes the extent to which students evaluated the course as motivating ('motivation').

The power calculation of the *t*-tests for these evaluation factors was computed as the power to discover small effects ($d = 0.20$), calculated taking the non-inferiority hypothesis into consideration. Based on this effect size and the sample sizes, the power to detect these effects was around 15%, indicating low power. The independent *t*-tests comparing the factor scores between the conditions showed significant difference between the conditions on the task value factor ($p < .001$). Of these two conditions, the virtual reality group rated the task value lower than the face-to-face group. This effect was quite large: Cohen's $d = 1.33$. The effects of condition on the other factors were non-significant: $p = .18$ for the informativeness factor and $p = .734$ for the motivation factor. The effect size for the informativeness factor was medium with the virtual reality condition scoring somewhat higher ($d = 0.46$, CI -0.21 to 1.12) and the effect size for the motivation factor was trivial with the face-to-face sample scoring slightly higher than the virtual reality sample ($d = 0.11$, CI -0.54 to 0.77). Neither of these confidence intervals were positioned within the non-inferiority interval of -0.10

Table 4

Factor loadings for the first 3 principal components.

Factor	Items	Factor loadings
1	Recommend VR	0.88
	Task realistic	0.83
	Task motivating	0.75
	Feedback valuable	0.62
2	Feedback valuable	0.59
	Feedback useful	0.80
	Course valuable	0.71
3	Course motivating	0.99

Table 5
Results *t*-test and TOST procedure closed evaluation questions.

Condition	VR		Control						
Factor	Mean (sd)	n	Mean (sd)	n	*t*	df	*d*	CI *d* lower	CI *d* higher
Task value	−0.59 (0.84)	17	0.53 (0.83)	19	−3.98	34	1.33	0.59	2.04
Informativeness	0.24 (0.90)	17	−0.21 (1.06)	19	1.37	34	0.46	−0.21	1.12
Motivation	−0.06 (1.18)	17	0.05 (0.84)	19	−0.34	34	0.11	−0.54	0.77

to 0.10. The results are summarized in Table 5.

The answers to the four open questions on the evaluation questionnaire were also analysed. Table 6 (see appendices for Tables 6–9) shows which aspects of non-verbal communication students reported receiving feedback on in both conditions. All the sub-criteria relating to non-verbal communication (i.e. use of voice, eye contact, posture and gestures), as described in the 'oral presentation skills' rubric, were named in both groups. However, students who presented in the virtual reality condition reported receiving relatively more feedback on aspects related to 'use of voice' (i.e. articulation, intonation, words per minute) compared with the control group.

With regard to feedback on aspects that were perceived as 'missing' by the students, the differences between the conditions are shown in Table 7. Students in both conditions missed feedback on the content and structure of their presentation to some extent, but students in the experimental condition also noted a lack of feedback on posture, gestures and movements, on the effect of their presentation on the audience and on facial expressions and mimicry. Of the students in the control condition, 68% said they did not miss any feedback at all.

Differences in perception between the two conditions are also evident in Table 8, which shows the perceived value of the presentation task for developing students' oral presentation competence. Although students in both conditions considered 'practising their presentation' equally relevant for their presentation competence development, they differed in their opinions on why the feedback related to these tasks was perceived as relevant. Students in the control condition emphasised 'the diversity of feedback aspects' and the extent to which the feedback was 'constructive, positively formulated with tips and tricks', while students in the experimental condition described the feedback they received as detailed and analytical. These students also pointed out that they perceived the presentation task as relevant but missed the tension and interaction with a real audience.

Finally, students were asked whether they believed the virtual reality-based task could replace a face-to-face presentation task (see Table 9). The majority of the students considered this task to complement a face-to-face presentation task, since virtual reality offers the opportunity to obtain detailed and analytical feedback, but they missed having a realistic audience.

5. Conclusions and discussion

Within the context of higher education, this study aimed to examine the effectiveness of a virtual reality-based task for practising presentations and facilitating feedback with regard to several essential components of students' presentation competence: cognition, behaviour and attitudes towards presenting. Learning outcomes demonstrated significant progress in all three components between the first and second presentation, both in the experimental condition and the control condition of regular expert feedback. In line with the results of a previous experiment in this field (Van Ginkel et al., 2015b), the assumption of a certain interrelationship between these oral presentation competence aspects was reaffirmed in this study (Mulder, 2014; Mulder & Winterton, 2017; Van Ginkel et al., 2015a). Furthermore, the results revealed significant improvements in all three presentation competence components, with no difference between the experimental and control condition in this specific sample. Although the conditions differed in terms of the environment for practising a presentation and providing feedback, the lack of difference in impact might be caused by the presence of an expert for delivering feedback in both conditions. This supports previous findings which highlight that teachers are regularly named as crucial actors in terms of encouraging student learning (Reis & Renzulli, 2010). As well as their essential function as role models for their students (Van Haaren & Van der Rijst, 2014), teachers also act as crucial facilitators of verbal feedback in the development of students' competencies (Porte, Xeroulis, Reznick, & Dubrowski, 2007). More specifically, in the context of presentation skills courses, teacher feedback scored highest on feedback quality criteria compared with other common feedback sources in tertiary education (Van Ginkel et al., 2016). The provision of high-quality feedback from teachers may therefore have encouraged the development of students' oral presentation competence in both the experimental and the control group.

Another argument for the lack of difference between the conditions can be deduced from the evaluation questionnaire completed by all participating students. Although students differed in their opinions of the task value, no differences in scores were found for one of the essential educational design principles for fostering oral presentation competence, which concerns feedback. Since students' scores of the value of the received feedback were acceptable and comparable in both conditions, it could be argued that this crucial learning environment characteristic (Van Ginkel et al., 2015a) was ensured in both conditions to support the learning processes. Although the expert input was different in the two conditions, the results turned out to be comparable. Furthermore, answers to the open questions on the same questionnaire revealed that, despite similar scores regarding this principle, students' scores varied in their arguments. While students in the control group appreciated the feedback received because of the diversity of feedback aspects and its constructive manner, students from the experimental condition emphasised the detailed and analytical characteristics of the received feedback. These insights call for the further refinement of the design principle relating to the type of feedback required for developing

oral presentation competence (Van Ginkel et al., 2015a). As well as diverse and constructive feedback, analytical characteristics should also be integrated to guarantee the provision of high-quality feedback. We therefore agree with other researchers in this field (e.g. Merchant et al., 2014; Sitzmann, 2011; Vogel et al., 2006) in that such an innovative technology should not be adopted in higher education curricula without carefully considering the integration of this design principle. Improvements can also still be made regarding the value of virtual reality-based tasks, since students reported several 'missing' non-verbal communication aspects in the feedback they received and a lack of tension and interaction with the audience in the virtual environment. This could explain the finding that students evaluated the task value of the virtual reality condition less positively than the face-to-face condition.

The small sample size is a limitation in this study. Although we demonstrate that the conditions score comparably regarding their impact on students' development of oral presentation competence, the effect could not be generalised to the population, possibly due to sample size limitations. A small sample leads to wide confidence intervals in the TOST procedure, and therefore low power. Consequently, research with a larger sample is needed to examine population effects. Nevertheless, this study demonstrated that, in this sample, oral presentation competence improved equally in the experiment in the virtual reality condition and the face-to-face condition.

Another limitation, as mentioned earlier, is that virtual reality may replace the teacher as a feedback source. An essential added value of this study relates to the combination of automated feedback and expert feedback based on the interpretation of the automated feedback. Within this study, presentation experts were present in both conditions and students placed a high value on the feedback. However, virtual reality technology is developing rapidly, and we therefore recommend new research focusing on the impact of a virtual reality-based task for delivering feedback on students' oral presentation competence. This is especially important, considering that new virtual reality environments are being developed that provide the presenter with qualitative feedback messages derived from the quantitative data delivered in the feedback reports. For example, if the feedback report on speech frequency (measured in Hz) shows a horizontal line during the introduction of the presentation, a qualitative feedback message could appear on the computer screen that is based on the quantitative information in the virtual reality system. Such a message could be formulated as follows: 'Regarding the use of your voice, try to vary intonation during your introduction. This may help you attract and hold your audience's attention.' These feedback messages reflect the constructive feedback that was highly appreciated by the students in the control condition. To guarantee the quality of such feedback messages, the content-related and form-related quality criteria for feedback on presentation behaviour (Van Ginkel et al., 2016) are adopted as standard. Such a virtual reality-based presentation task could both encourage self-regulation skills in students and potentially replace the role of the teacher as a feedback source while rehearsing presentations. However, experimental research should be carried out to verify and test this assumption.

A third limitation of this study concerns students' unfamiliarity with the use of virtual reality for learning purposes, as addressed earlier by Hew and Cheung (2010). This aspect may influence the results, both in terms of the impact on developing oral presentation competence and perceptions of using the innovative technology. Despite the issue of unfamiliarity in the experimental condition, it is noteworthy that both conditions led to similar effects. In this study, students in the experimental condition received just five minutes of instruction before conducting their presentation in virtual reality. Taking this into consideration, more attention in research and practice should be devoted to training participants prior to carrying out a virtual reality-based task. In line with Van Ginkel et al. (2015a), instructing students about virtual reality, setting personal learning objectives, modelling other presenters in such an environment, practising a mini-presentation in virtual reality and receiving feedback from the system could be regarded as essential characteristics of a training programme for students entering virtual environments.

Regarding quality criteria of this study, aspects of reliability and validity are important to discuss. One of the strengths of this study is the high internal reliability scores of the adopted instruments for measuring cognition, skills and attitudes toward presenting. Details of these scores are provided in the methods section of this manuscript. Moreover, an acceptable inter-rater reliability for performance measurements of students' oral presentations was ensured (see methods section). However, in order to replicate such a study in a realistic presentation environment, guiding presentation experts prior to the experiment is crucial as we did in this experiment: all experts were individually briefed by the leader of the presentation skills course and the first author. During these sessions, experts should receive identical instructions on how to facilitate feedback processes in both conditions depending on the performance measurement. Such instructions include: (1) the procedure for the presenter with instructions on presentation performance and receiving feedback, (2) instructions to restrict feedback to five minutes to ensure similar feedback times, and (3) an 'oral presentation skills' rubric for each expert to guide the delivery of feedback after the presentation in relation to the presentation delivery aspects (Van Ginkel et al., 2017).

Besides reliability aspects, the following aspects of validity are essential for future researchers in this field: ecological validity, internal validity and construct validity. First, this study on a virtual reality-based presentation task for delivering feedback is conducted in realistic presentation skills courses in the higher education context which ensures the ecological validity of the study. As such, aspects of the presentation task (e.g. five minutes on a self-selected topic), combining practice and feedback and including the crucial design principles for developing oral presentation competence in the design of the course (Van Ginkel et al., 2015a,b) can be emphasized as essential. Second, the internal validity of this study should be taken into account. Future studies could optimise the internal validity of such an experiment by measuring cognition towards presenting, presentation behaviour and attitude towards presenting directly before and directly after the experimental condition and compare that with the control condition. In this study, these components of oral presentation competence were measured at the start and end of the presentation course, which could have led to data which would have allowed for the measurement of not only the effects of the condition but also the effects of the whole course. Third, the construct validity can be further specified in future research. This relates to specifying the presentation delivery aspects of the presentation skills components. Previous research emphasized that aspects such as 'convincingness' and 'line of reasoning' are crucial variables in the delivery of an effective presentation (Noroozi, Biemans, Weinberger, Mulder, & Chizari, 2013a).

Although the presentation skills rubric used in this study has been validated by a panel of presentation experts (Van Ginkel et al., 2017), future research could focus on both extending the rubric with the aforementioned aspects as well as specifying presentation delivery aspects. For example, an aspect such as 'use of voice' could be subdivided into the following aspects: speech frequency, speech rate and speech volume (Van Ginkel et al., 2017).

Based on limitations, discussion and suggestions for future research, we see several new research directions for future research within this area. To encourage the comparability of the audiences (e.g. Ayres, 2009; Beatty & Friedland, 2009; McKinney et al., 2010) in virtual reality presentation studies, it is suggested to separate the instruction, presentation practice and feedback on presentation delivery aspects in the experiment. To guarantee social facilitation effects, students could be instructed by one presentation expert before conducting their presentation and receive feedback from this expert based on presentation delivery aspects. Furthermore, the presentation should be given in a classroom setting in the virtual reality condition (rather than a large audience such as at a conference), and the control condition should reflect a classroom setting with the same number of peers as avatars in the virtual reality audience.

Follow-up studies should focus on manipulating the characteristics of the learning environment with the aim to increase the impact of virtual reality-based tasks that foster oral presentation competence. Inspired by the suggestions of Hew and Cheung (2010), longitudinal studies could reveal (1) if oral presentation performances can be influenced if participants first become more familiar with the technology, and (2) whether students' perceptions of virtual reality change over a longer period of time. Future studies could also concentrate on the potential of combining different types of feedback for developing students' oral presentation competence, such as diverse, constructive and analytical feedback, guided by experimental designs. Moreover, virtual reality technology is able to deliver both 'delayed' feedback, based on a report and explained by an expert (as in this study), and 'immediate' feedback, which is directly registered and displayed by the system in the virtual learning environment. This could be an interesting option for follow-up studies, since researchers in the presentation research field (King, Young, & Behnke, 2000) have noted that immediate feedback could improve presentation delivery aspects (e.g. stimulate eye contact), whereas delayed feedback is more effective in encouraging presentation aspects that require deliberate and effortful processing (e.g. altering the length of a presentation introduction). The benefit of immediate feedback through virtual reality is that it could potentially replace the role of the teacher as feedback provider.

Other future studies on virtual reality should be conducted in different educational contexts with students with varying characteristics (e.g. gender, age and educational level) regarding the aspect of representativeness. Such a direction of future research includes distinguishing between student characteristics in learning through a virtual reality-based task (Vogel et al., 2006), since Chen, Toh, and Ismail (2005) reported that students could differ in their perceptions of virtual reality depending on their preferred learning activities. In line with this, it is questionable whether students vary in their preference for detailed and analytical feedback as reported in the evaluations of the experimental group in this explorative study. Other characteristics related to the 'student' actor and relevant for future research in this specific field are potential differences in perceptions of virtual reality between (1) student traits (such as gender, age and educational level), (2) experienced and non-experienced students regarding presenting in virtual reality, (3) students from different sociocultural traditions – for example teacher-centred versus student-centred higher educational curricula – (see Hew & Cheung, 2010), and (4) students with varying personal goals or learning patterns that influence their perceptions of the value of feedback types for developing presentation competencies (De Kleijn, Meijer, Brekelmans, & Pilot, 2012).

Finally, the use of virtual reality-based tasks for practising presentations and delivering high-quality feedback has several implications for educational practice. Firstly, the results of this study show that the interaction with the virtual audience and the tension that presenting to an audience produces need to be further developed in the technology. This will ensure that the experience imitates real-life, which will help develop oral presentation competence even further. Secondly, virtual reality-based tasks should be integrated in educational practice alongside face-to-face learning processes, both for practising presentations and delivering high-quality feedback. This integrated approach is based on the finding that the virtual reality-based presentation task proved to be as effective as face-to-face presentations with expert feedback, and there are benefits to the complementary feedback delivered after a virtual reality-based task. To prevent the adoption of stand-alone activities (Sitzmann, 2011), teachers, tutors and students should be specifically trained before entering the learning environment and ensure that they provide feedback that is diverse and constructive, as well as detailed and analytical in nature. However, further research is needed to examine how, and under which conditions, virtual reality-based tasks could potentially replace the role of the teacher, to ensure the effective and efficient integration of these rehearsal tasks in presentation courses. Finally, although innovative technologies are increasingly being adopted in higher education curricula, the effective and efficient integration of virtual reality-based tasks for practising presentations and delivering feedback requires substantial investments in time and financial resources (Merchant et al., 2014). Such considerations should be aligned with the strategic policy of higher education institutions.
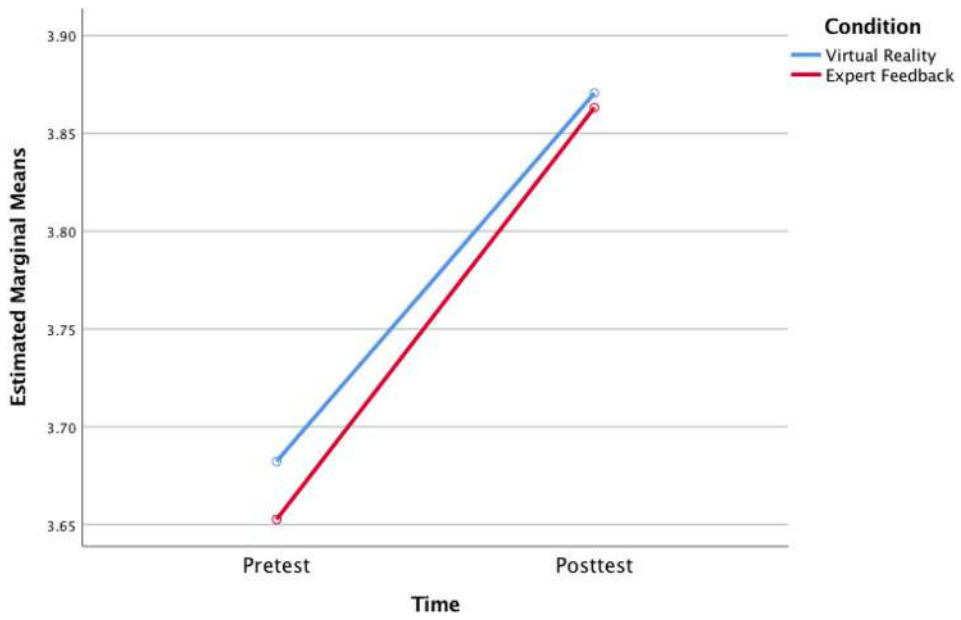
Funding

Appendix

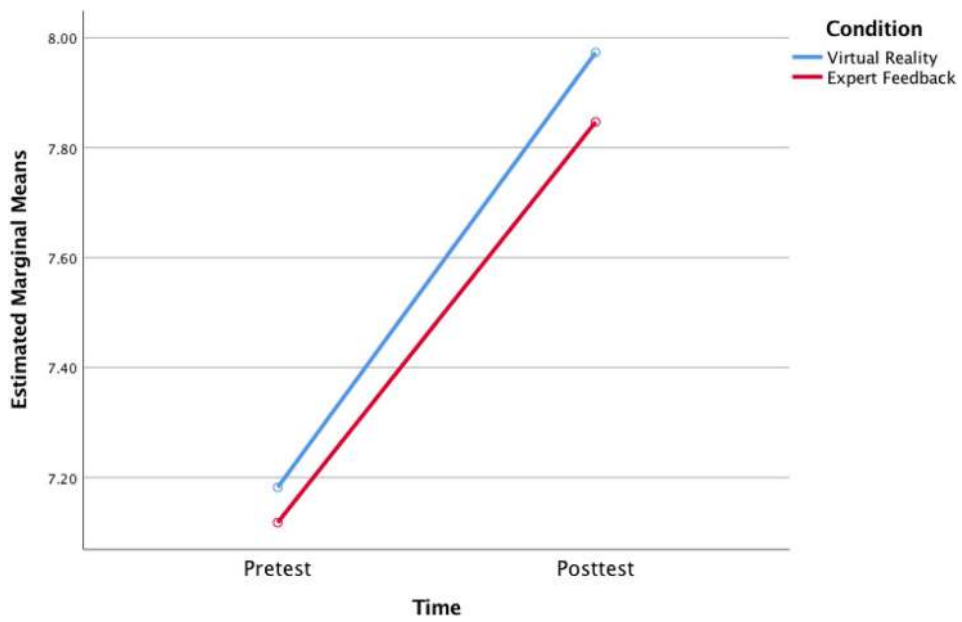**Fig. 5.** Effect task*time on attitude towards presenting.

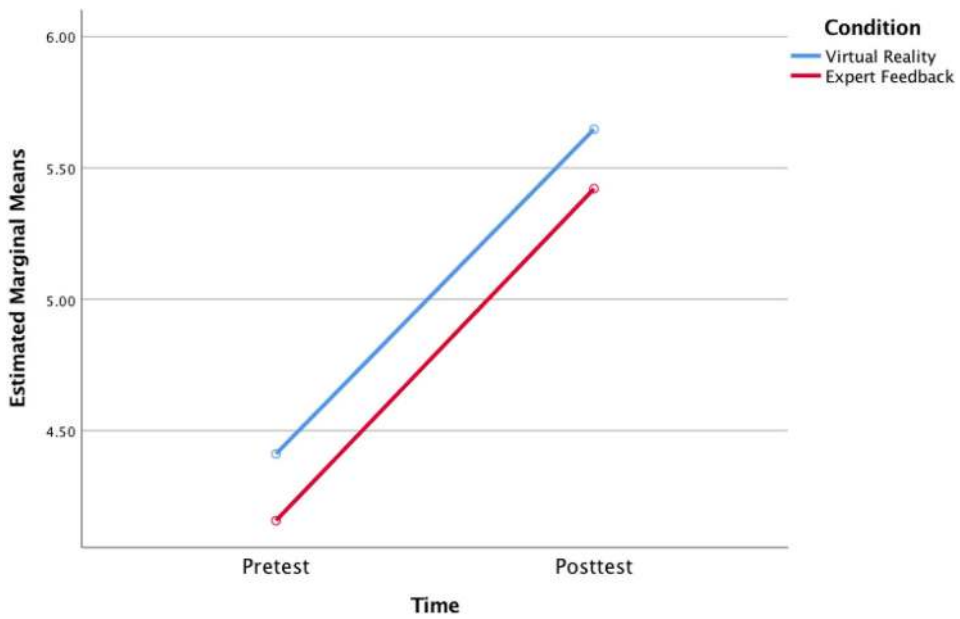**Fig. 6.** Effect task*time on presentation behaviour.

Fig. 7. Effect task*time on cognition towards presenting.
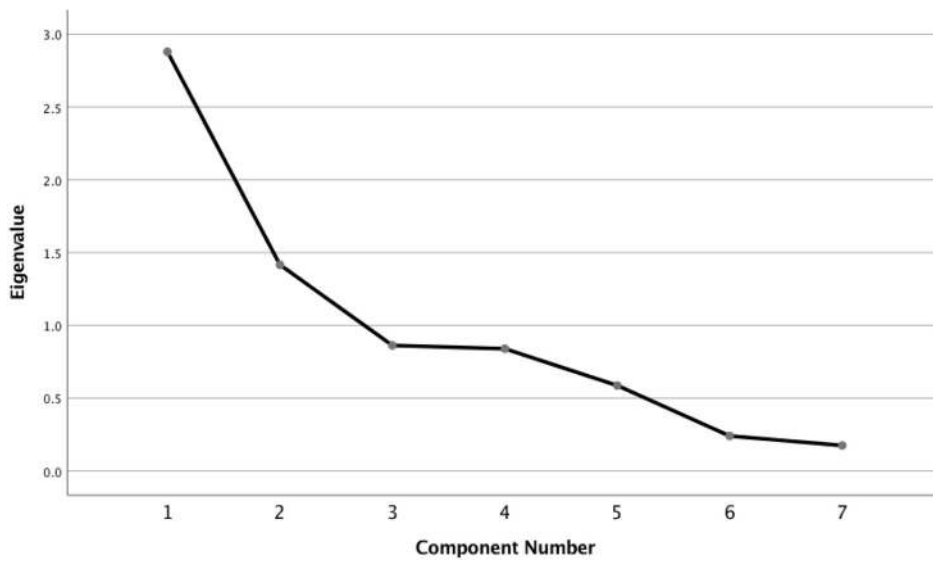
Fig. 8. Scree plot PCA.

Table 6
Open questions feedback received.

Type of feedback	VR		Expert feedback	
	Count	%	Count	%
Use of voice	17	100	15	78.90
Eye contact	5	29.40	5	26.30
Posture	9	52.90	15	78.90
Gestures	3	17.6	10	52.60
Remaining aspects	4	23.50	10	52.60

Table 7

Open questions feedback missed.

Type of feedback	VR		Expert feedback	
	Count	%	Count	%
Content of presentation	1	5.90	3	15.80
Structure of presentation	4	23.50	5	26.30
Posture, gestures & movements	5	29.40	0	0.00
Effects on audience	5	29.40	1	5.30
Nerves	0	0.00	2	10.50
Facial expressions	3	17.60	0	0.00
Use of words	1	5.90	1	5.30
No feedback missed	2	11.80	13	68.40

Table 8

Relevance of presentation task.

Reason	VR		Expert feedback	
	Count	%	Count	%
Detailed feedback	11	64.70	3	15.80
Diverse feedback	0	0.00	9	47.40
Constructive feedback	1	5.90	6	31.60
Practice	4	23.50	4	21.10
Tension & interaction	3	17.60	1	5.30
Walk & gestures	2	11.80	0	0.00
Not relevant	1	5.90	0	0.00

Table 9

Viability VR for replacing face-to-face feedback[1].

Type of feedback	VR	
	Count	%
Replacement	2	11.80
Complementary	12	70.60
No replacement	2	11.80

References

Anderson, P. L., Zimand, E., Hodges, L. F., & Rothbaum, B. O. (2005). Cognitive behavioral therapy for public-speaking anxiety using virtual reality for exposure. *Depression and Anxiety, 22*(3), 156–158.

Andolsek, D. L. (1995). Virtual reality in education and training. *International Journal of Instructional Media, 22*(2), 145–155.

Attali, Y., & van der Kleij, F. (2017). Effects of feedback elaboration and feedback timing during computer-based practice in mathematics problem solving. *Computers & Education, 110*, 154–169.

Ayres, J. (2009). Situational factors and audience anxiety. *Communication Education, 39*(4), 283–291.

Batrinca, L., Stratou, G., Shapiro, A., Morency, L. P., & Scherer, S. (2013). Cicero-towards a multimodal virtual audience platform for public speaking training. *International workshop on intelligent virtual agents* (pp. 116–128). Berlin: Springer.

Beatty, M. J., & Friedland, M. H. (2009). Public speaking state anxiety as a function of selected situational and predispositional variables. *Communication Education, 39*(2), 142–147.

Bower, M., Cavanagh, M., Moloney, R., & Dao, M. (2011). Developing communication competence using an online video reflection system: Pre-service teachers' experiences. *Asia-Pacific Journal of Teacher Education, 39*(4), 311–326.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Calcich, S., & Weilbaker, D. (1992). Selecting the optimum number of in-class sales presentations. *Marketing Education Review, 2*(1), 31–33.

Chan, V. (2011). Teaching oral communication in undergraduate science: Are we doing enough and doing it right? *Journal of Learning Design, 4*(3), 71–79.

Chen, C., Toh, S., & Ismail, W. (2005). Are learning styles relevant to virtual reality? *Journal of Research on Technology in Education, 38*(2), 120–128.

Chollet, M., Wörtwein, T., Morency, L. P., Shapiro, A., & Scherer, S. (2015). Exploring feedback strategies to improve public speaking: An interactive virtual audience framework. *Proceedings of the 2015 ACM international joint conference on pervasive and ubiquitous computing* (pp. 1143–1154). ACM.

Clarke, V., & Braun, V. (2013). Teaching thematic analysis: Overcoming challenges and developing strategies for effective learning. *The Psychologist, 26*(2), 120–123.

Coller, B. D., & Scott, M. J. (2009). Effectiveness of using a video game to teach a course in mechanical engineering. *Computers & Education, 53*(3), 900–912.

Coller, B. D., & Shernoff, D. J. (2009). Video game-based education in mechanical engineering: A look at student engagement. *International of Engineering Education, 25*, 308–317.

De Grez, L. (2009). *Optimizing the instructional environment to learn presentation skills.* Gent: Dissertation: Universiteit Gent.

De Grez, L., Valcke, M., & Roozen, I. (2009). The impact of goal orientation, self-reflection and personal characteristics on the acquisition of oral presentation skills.

European Journal of Psychology of Education, 24(3), 293–306.

De Jong, T. (1991). Learning and instruction with computer simulations. *Education & Computing, 6*, 217–229.

De Kleijn, R., Meijer, P. C., Brekelmans, M., & Pilot, A. (2012). Curricular goals and personal goals in master's thesis projects: Dutch student-supervisor dyads. *International Journal of Higher Education, 2*(1), 1–11.

Dubovi, I., Levy, S. T., & Dagan, E. (2017). Now I know how! the learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation. *Computers & Education, 113*.

Falchikov, N. (2005). *Improving assessment through student involvement: Practical solutions for aiding learning in higher and further education.* New York: RoutledgeFalmer.

Galas, C., & Ketelhut, D. J. (2006). River City, the MUVE. *Learning and Leading with Technology, 33*(7), 31–32.

Haber, R. J., & Lingard, L. A. (2001). Learning oral presentation skills, a rhetorical analysis with pedagogical and professional implications. *Journal of General Internal Medicine, 16*(5), 308–314.

Harris, S. R., Kemmerling, R. L., & North, M. M. (2002). Brief virtual reality therapy for public speaking anxiety. *CyberPsychology and Behavior, 5*(6), 543–550.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112.

Hawkins, D. G. (1995). Virtual reality and passive simulators: The future of fun. In F. Biocca, & M. R. Levy (Eds.). *Communication in the age of virtual reality* (pp. 159–189). Hillsdale, NJ: Lawrence Erlbaum.

Hayes, N. (2000). *Doing psychological research.* Buckingham: Open University Press.

Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33–55.

Hung, S. T. A. (2016). Enhancing feedback provision through multimodal video technology. *Computers & Education, 98*, 90–101.

Jang, S., Vitale, J. M., Jyung, R. W., & Black, J. B. (2017). Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment. *Computers & Education, 106*, 150–165.

Jonsson, A., & Svingby, G. (2007). The use of scoring rubrics: Reliability, validity and educational consequences. *Educational Research Review, 2*, 130–144.

Kang, N. (2016). *Public speaking in virtual reality: Audience design and speaker experiences.* Dissertation: TU Delft, Delft.

Kerby, D., & Romine, J. (2009). Develop oral presentation skills through accounting curriculum design and course-embedded assessment. *Journal of Education for Business, 85*(3), 172–179.

Kim, S., Kogan, J. R., Bellini, L., & Shea, J. (2005). A randomized-controlled study of encounter cards to improve oral case presentation skills of medical students. *Journal of General Internal Medicine, 20*(8), 743–747.

King, P., Young, M., & Behnke, R. (2000). Public speaking performance improvement as a function of information processing in immediate and delayed feedback interventions. *Communication Education, 49*(4), 365–374.

Krause, U. M., Stark, R., & Mandl, H. (2009). The effects of cooperative learning and feedback on e-learning in statistics. *Learning and Instruction, 19*(2), 158–170.

Lakens, D. (2017). Equivalence tests: A practical primer for t tests, correlations, and meta-analyses. *Social Psychological and Personality Science, 8*(4), 355–362.

LaViola, J. J., Kruijff, E., McMahan, R. P., Bowman, D. A., & Poupyrev, I. (2017). *3D user interfaces: Theory and practice* (2nd ed.). Boston: Addison-Wesley.

Lee, J. (1999). Effectiveness of computer-based instructional simulation: A meta-analysis. *International Journal of Instructional Media, 26*(1), 71–85.

Lee, E. A. L., & Wong, K. W. (2014). Learning with desktop virtual reality: Low spatial ability learners are more positively affected. *Computers & Education, 79*, 49–58.

Lorenzo, G., Lledó, A., Pomares, J., & Roig, R. (2016). Design and application of an immersive virtual reality system to enhance emotional skills for children with autism spectrum disorders. *Computers & Education, 98*, 192–205.

Mayer, R. E., & Moreno, R. (2002). Aids to computer-based multimedia learning. *Learning and Instruction, 12*(1), 107–119.

McKinney, M. E., Gatchel, R. J., & Paulus, P. B. (2010). The effects of audience size on high and low speech-anxious subjects during an actual speaking task. *Basic and Applied Social Psychology, 4*(1), 73–87.

McNamara, D. S., Jackson, G. T., & Graesser, A. (2009). Intelligent tutoring and games (ITAG). *AIED, 14*, 44–65.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education, 70*, 29–40.

Mixamo (2018). *Mixamo. Animated 3D characters. No 3D knowledge required. Rapidly create, rig and animate unique characters for design projects. (2018).* https://www.mixamo.com/#/ (accessed 20.03.18).

Mulder, M. (2014). Conceptions of professional competence. In S. Billett, C. Harteis, & H. Gruber (Eds.). *International Handbook on Research into professional and practice-based learning.* Dordrecht: Springer.

Mulder, M., & Winterton, J. (2017). Introduction. In M. Mulder (Ed.). *Competence-based vocational and professional education. Bridging the worlds of work and education* (pp. 1–43). Cham: Springer.

Nichols, S., & Patel, H. (2002). Health and safety implications of virtual reality: A review of empirical evidence. *Applied Ergonomics, 33*(3), 251–271.

Noroozi, O., Biemans, H. J., & Mulder, M. (2016). Relations between scripted online peer feedback processes and quality of written argumentative essay. *The Internet and Higher Education, 31*, 20–31.

Noroozi, O., Biemans, H. J., Weinberger, A., Mulder, M., & Chizari, M. (2013a). Scripting for construction of a transactive memory system in multidisciplinary CSCL environments. *Learning and Instruction, 25*(1), 1–12.

Noroozi, O., Weinberger, A., Biemans, H. J., Mulder, M., & Chizari, M. (2013b). Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. *Computers & Education, 61*, 59–76.

Opris, D., Pintea, S., García-Palacios, A., Botella, C., Szamosközi, Ş., & David, D. (2012). Virtual reality exposure therapy in anxiety disorders: A quantitative meta-analysis. *Depression and Anxiety, 29*(2), 85–93.

Panadero, E., & Jonsson, A. (2013). The use of scoring rubrics for formative assessment purposes revisited: A review. *Educational Research Review, 9*(0), 129–144.

Pasqualotti, A., & Freitas, C. M. D. S. (2002). MAT3D: A virtual reality modeling language environment for the teaching and learning of mathematics. *CyberPsychology & Behavior, 5*(5), 409–422.

Pertaub, D.-P., Slater, M., & Barker, C. (2001). An experiment on fear of public speaking in virtual reality. In J. D. Westwood, H. M. Hoffman, G. T. Mogel, & D. Stredney (Eds.). *Medicine meets virtual reality* (pp. 372–378). IOS Press.

Popov, V., Noroozi, O., Barrett, J. B., Biemans, H., Teasley, S. D., Slof, B., et al. (2014). Perceptions and experiences of, and outcomes for, university students in culturally diversified dyads in a computer-supported collaborative learning environment. *Computers in Human Behavior, 32*, 186–200.

Porte, M. C., Xeroulis, G., Reznick, R. K., & Dubrowski, A. (2007). Verbal feedback from an expert is more effective than self-accessed feedback about motion efficiency in learning new surgical skills. *The American Journal of Surgery, 193*(1), 105–110.

Prins, F. J., De Kleijn, R., & Van Tartwijk, J. (2015). Students' use of a rubric for research theses. *Assessment & Evaluation in Higher Education*.

Reis, S. M., & Renzulli, J. S. (2010). Is there still a need for gifted education? An examination of current research. *Learning and Individual Differences, 20*(4), 308–317.

Reitmeier, C. A., & Vrchota, D. A. (2009). Self-assessment of oral communication presentations in food science and nutrition. *Journal of Food Science Education, 8*(4), 88–92.

Richards, D., & Taylor, M. (2015). A Comparison of learning gains when using a 2D simulation tool versus a 3D virtual world: An experiment to find the right representation involving the Marginal Value Theorem. *Computers & Education, 86*, 157–171.

Riva, G. (2003). Applications of virtual environments in medicine. *Methods of Information in Medicine, 42*, 524–534.

Schneider, J., Börner, D., Van Rosmalen, P., & Specht, M. (2015). Presentation trainer: What experts and computers can tell about your nonverbal communication. *Journal of Computer Assisted Learning, 33*, 164–177.

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology, 64*(2), 489–528.

Smith, C. M., & Sodano, T. M. (2011). Integrating lecture capture as a teaching strategy to improve student presentation skills through self-assessment. *Active Learning in Higher Education, 12*(3), 151–162.

Tanveer, M. I., Lin, E., & Hoque, M. E. (2015). Rhema: A real-time in-situ intelligent interface to help people with public speaking. *Proceedings of the 20th international conference on intelligent user interfaces* (pp. 286–295). ACM.

Tobias, S., & Fletcher, J. D. (2010). Introduction. In S. Tobias, & J. D. Fletcher (Eds.). *Computer games and instruction* (pp. 3–16). Charlotte, NC: Information Age.

Unity Technologies. (2014). *Unity. (2014).* https://unity3d.com/ (accessed 26.10.04).

Van Ginkel, S., Gulikers, J., Biemans, H., & Mulder, M. (2015a). Towards a set of design principles for developing oral presentation competence: A synthesis of research in higher education. *Educational Research Review, 14*, 62–80.

Van Ginkel, S., Gulikers, J., Biemans, H., & Mulder, M. (2015b). The impact of the feedback source on developing oral presentation competence. *Studies in Higher Education,* 1–15.

Van Ginkel, S., Gulikers, J., Biemans, H., & Mulder, M. (2016). Fostering oral presentation performance: Does the quality of feedback differ when provided by the teacher, peers or peers guided by tutor? *Assessment and Evaluation in Higher Education,* 1–14.

Van Ginkel, S., Laurentzen, R., Mulder, M., Mononen, A., Kyttä, J., & Kortelainen, M. J. (2017). Assessing oral presentation performance: Designing a rubric and testing its validity with an expert group. *Journal of Applied Research in Higher Education, 9*(3), 474–486.

Van Haaren, M., & Van der Rijst, R. (2014). Teaching talented students at a research-intensive university. In M. V. C. Wolfensberger, L. Drayer, & J. J. M. Volker (Eds.). *Pursuit of excellence in a networked society: Theoretical and practical approaches* (pp. 39–46). Münster: Waxmann.

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research, 34*(3), 229–243.

Washer, P. (2007). Revisiting key skills: A practical framework for higher education. *Quality in Higher Education, 13*(1), 57–67.

Wuensch, K. (2012). *Equivalence tests for two means using differences.* https://www.ncss.com/wp-content/themes/ncss/pdf/Procedures/PASS/Equivalence_Tests_for_Two_Means_using_Differences.pdf (accessed 21.03.18).

Wuensch, K. (2014). *Tests of equivalence and confidence intervals for effect sizes.* http://core.ecu.edu/psyc/WuenschK/docs30/Equivalence-EffectSizeCI.pdf (accessed 21.03.18).