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PAST AND FUTURE APPLICATIONS OF 3-D (VIRTUAL REALITY) TECHNOLOGY

N. Foreman[a, b], L. Korallo[a, b]

[a] Middlesex University, London, NW4 4BT, UK, n.foreman@mdx.ac.uk
[b] ITMO University, Saint Petersburg, 197101, Russian Federation

Abstract. Virtual Reality (virtual environment technology, VET) has been widely available for twenty years. In that time, the benefits of using virtual environments (VEs) have become clear in many areas of application, including assessment and training, education, rehabilitation and psychological research in spatial cognition. The flexibility, reproducibility and adaptability of VEs are especially important, particularly in the training and testing of navigational and way-finding skills. Transfer of training between real and virtual environments has been found to be reliable. However, input device usage can compromise spatial information acquisition from VEs, and distances in VEs are invariably underestimated. The present review traces the evolution of VET, anticipates future areas in which developments are likely to occur, and highlights areas in which research is needed to optimise usage.

Keywords: virtual reality technology, applications, benefits and drawbacks, future applications, future research.

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ПРОШЛОЕ И БУДУЩЕЕ 3-D ТЕХНОЛОГИЙ ВИРТУАЛЬНОЙ РЕАЛЬНОСТИ

Н. Форман[a, b] Л. Коралло[a, b]

[a] Миддлсекский университет, Лондон, NW4 4BT, Великобритания, n.foreman@mdx.ac.uk
[б] Университет ИТМО, Санкт-Петербург, 197101, Российская Федерация

Аннотация. Виртуальная реальность (метод виртуальной среды, VET) широко используется на протяжении двадцати лет. За этот период стали очевидными преимущества использования технологий виртуальной окружающей среды во многих областях, включая оценку рисков и обучение, образование, реабилитацию и психологические исследования познавательной способности в пространстве. Гибкость, воспроизводимость и адаптируемость методов виртуальной среды особенно важны при тренировке способности операторов к ориентации на местности. Однако, к сожалению, использование оператором пространственной информации от входных устройств виртуальной реальности приводит к неизменному преуменьшению оценки расстояния до наблюдаемых объектов. В данной работе выполнен обзор эволюции технологий создания виртуальной среды и прогнозирования вероятных сфер их применения. Подчеркиваются перспективные направления оптимизации использования человеком новых технологий.

Ключевые слова: технологии виртуальной реальности, применение 3D технологий, преимущества и недостатки виртуальной среды, эволюция 3D технологий

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Авторы выражают благодарность за интересные и содержательные обсуждения вопросов, касающихся виртуальной реальности и пространственных когнитивных способностей, коллегам и друзьям из Университета ИТМО, Санкт-Петербург, факультета психологии СПбГУ и Института физиологии имени И.П. Павлова РАН, особенно профессору Юрию Евгеньевичу Шелепину, а также Президенту Российско-Казахского университета Темирхану Байбосуновичу Бердимуратову, доктору Данне Наурзалиной, заведующей кафедрой психологии Гульфие Муратовне Яппаровой и членам регионального отдела образования г. Актобе.

Introduction

Virtual Reality (VR) is an objective rather than an achievement; the concept of generating a realistic (“real”) environment in which an individual feels a sense of presence is not easily achieved, even using the best software and hardware such as head-immersion helmets. Jaron Lanier first coined the term Virtual Reality some 30 years ago, and although VR has improved in that time, the thought that an individual could place a VR helmet on their head, let alone view a computer screen, and feel “transported” to a computer generated world is not imminently in prospect, however authentic the graphics.

Virtual Reality is, nevertheless, in widespread use (though usage is not as widespread as originally envisaged at the height of VR fever in the 1990’s; see below.) Not surprisingly, VR was especially well developed by the gaming industry, where financial returns are guaranteed on substantial investments and for military applications where national funding is guaranteed to promote training of personnel involved in defence. There are many reasons why VR is preferred over other types of media. For example, the programmer/designer of a virtual environment is in complete control. Anything that can be imagined can be modelled using the right software. VR is of interest for this reason too: when the senior author ran training courses with Paul Wilson in VR in the 1990s for businesses in Italy and Portugal, we would typically introduce complete novices to very simple VR packages (the forerunners of later packages such as SuperScape) and instruct them on how to create simple objects using a relatively small number of polygons that could be adjusted, coloured and placed in a small VE. Our own experience had been in creating small school environments, rooms and other small spaces that could be navigated using a mouse or keyboard. However, we were amazed at the design skills of "students" working in those industries, who would often create really interesting and original models -- of virtual computers, for example -- using these primitive tools. Therefore, the ability to use VR successfully is determined by both programming skills and also the artistic skills required to make best use of it. Also, since we were also interested to know what were the particular benefits of using VEs in experimental research (to create and to use virtual environments, to navigate and way-find) psychologists could also make good use of VEs to investigate the ways in which people use landmarks and allocentric cues to find their way within a virtual world. VR is essentially "spatial"; indeed some referred to "VR soft-where". This enables all kinds of research possibilities [1]. If a psychologist wishes to investigate participants' establishment of a virtual "cognitive spatial map" of Paris, they could do it in Paris using maps and compasses, and having participants remember routes through the city or make pointing judgments to landmarks (see [2], [3] and [4] for methodologies). However, in a virtual environment one can manipulate the cue layout of the environment in any way, such as swapping the positions of the Eiffel tower and Arc de Triomphe, to determine the importance of each of those landmarks for Parisian way-finding, though this is clearly not a manipulation that it would be possible to use in the real Paris! A recent study has employed VR to investigate activity and passivity in relation to understanding an area of Bordeaux [5].

What is special about VR and why are its unique features useful?

As indicated above, the great benefit of using VR in research is its flexibility. Real worlds can be and artificial environments created from nothing. Moreover, the use of a VE can be repeated over and over again, so that an individual can be trained in an identical but repeated situation; of course difficulty can be titrated to provide a progressive learning experience. In Psychology, it is particularly useful to be able to test groups of people individually knowing that they have experienced precisely the same test situation, by virtue of their having viewed the same display. Some past studies (e.g., [6]; see below) have used passive and active groups for experimental comparisons, the latter group in control of their exploration, while the former group consisted of "yoked" controls, each individually matched to an active participant but observing the screen and thus watching exactly the same spatial displacements as made by the active participant, but without controlling the interface. Doing such a thing in reality is possible but it is difficult.

When VR first appeared, the senior author was personally doubtful about the authenticity of viewing a virtual world for conducting spatial research, not being convinced that people would acquire good quality spatial information from a virtual display particularly since some experimenters in the USA had emphasized the importance of inner ear mechanisms for generating comprehensive "spatial maps" when moving about in space [7]. These concerns were quickly dispelled after a few early experiments, conducted with colleagues in Leicester University [2, 8, 9, 10, 11], showed that both adults and children could view a VE and afterwards make accurate pointing judgements to indicate the directions of distant spatial locations, from various pointing locations to which they were taken within the virtual world. This ability relies on having a "spatial cognitive map" of the environment [12]; they should also be able to take short cuts and make detours in a VE using spatial mapping abilities (see [13] and [14]), and this is just the sort of thing that participants in VR studies have been shown to be able to do. Also, in the early studies and since, there was clearly very good transfer of learning between virtual and real equivalent environments [15, 16], in children and adults, but also, perhaps surprisingly, in children with disabling conditions (that were usually thought to render their spatial judgements poor) and in adults of advanced age whose spatial brain systems, such as the hippocampus [17], were conventionally thought to be compromised [2, 8; see below].

In other words, by and large, people behave in a VE much as they would in the real equivalent environment. This poses the question – one that has not often been addressed in spatial research – of what changes occur in the brain during navigation, changes which can kick in and operate effectively in both the real world but also in a virtual world? Clearly, when sitting passively in a chair, spatial systems in the brain are generally in abeyance; there is no point in computing relations among objects and between self and self-movement and environmental objects, since these relationships and computations only become important when movement occurs, especially movement initiated by the person concerned [18]. The matter could be addressed by recording brain activity using imaging procedures; it would be interesting to know which brain areas "light up" when an individual changes from their stationary state and begins to move about autonomously, for example on foot. However, since we now realise that virtual movement control is almost as effective as real movement in space, these brain areas should be detectable using timed self-directed movement in a VE. This application of VEs has yet to be investigated, though combining VEs with brain recordings has already been illuminating [19, 20].

Activity and passivity in virtual worlds

VR is clearly a unique medium, and paradoxical insofar as it is essentially passive (since participants are typically seated and view a screen or head immersion screens in a helmet) but it is active in that it engages the participant in self-initiated displacements so that they make active decisions about where to go and what to see and do, just as when they are walking about or driving car autonomously. Activity versus passivity (in both reality and in VR) has attracted a great deal of research attention. The general assumption was always that active exploration would always produce better spatial learning, and some found evidence for that. However the results were always mixed and controversial [6, 21]. What appeared to have escaped their notice is that use of VEs – particularly desktop VEs -- always involves some kind of abnormal participant activity such as moving a mouse or joystick or pressing keyboard keys. The most recent findings have led to the conclusion that interfacing with a VE is effectively a secondary task – a competing parallel task – that occupies some cognitive capacity leaving less available for spatial (working) memory [15, 22, 23]. This should not be a great surprise since "dual task" methodology has been used for many years to investigate spatial working memory capacity [22, 23] but the surprise is that it applies to VE usage and interactivity.

What applications have been successfully demonstrated?

VR has been beneficial in areas where visualisation in reality is not possible, such as illustrating structure and function in the brain or throughout the body, and using virtual manipulations to create novel and illuminating test protocols [24]. Here VR has developed in parallel with other 3-D media and procedures including functional Magnetic Resonance Imaging (fMRI). In early work in Leicester University (see above) the senior author's own research group was able to show that VEs could be used successfully to convey spatial knowledge of a building (such as a school) to children who might otherwise be permanently spatially impaired. Research had shown [25] that children with a variety of conditions that affected their mobility (including spina bifida, cerebral palsy and childhood arthritis) tended to make inaccurate pointing judgments when asked to point (with eyes closed) in the direction of prominent landmarks on their school campus. However, after several days of VR training in a virtual version of a novel school we showed that even children with debilitating conditions could learn a great deal about the novel environment and practically, find their way about successfully when they arrived there. Transfer from virtual to real environments was not quite equivalent, but sufficiently equivalent for all practical purposes (see [2, 9, 10]. In a similar study, using a virtual model of the Astley Clarke Building of Leicester University (at that time, the Psychology Department), we found that students in the department who used a wheelchair for their mobility, and were denied access to the basement area of the department (which had, at that time, no lift installed), told us what a relief it was to be able to visit the basement and to know "what was there". It made them feel that they understood the building in which they were learning. In truth, the basement area was not especially attractive or enlightening, but the example illustrates how limited experience from mobility restriction can have surprising consequences and that this can be overcome using a VE. The latter example illustrates another important point: some of those we tested had brain damage that must have affected spatial areas of the brain (such as hippocampal damage in cerebral palsy) but others did not (childhood arthritis), suggesting that spatial deficits could arise not from brain damage per se but rather secondarily from the consequences of brain damage that restricted mobility and undermined normal exploration and spatial decision-making [25]. Akhutina et al. [26] found that training with VEs successfully enhanced improvement in several cognitive skills in children with a range of brain insults, and in adults Brooks et al. [27] have found that residual route learning skills can be successfully trained in an amnesic patient in a virtual reconstruction of their hospital environment. Mobility training in a wheelchair can benefit from the use of VEs [28]. A great benefit of a VE in training is its safety; participants can make virtual errors and have virtual collisions without injuring anyone, or themselves.

Applications in education

Within education, VR has many potential benefits, for example linking children in widely different locations in mutual social interaction [29]. Special needs education may benefit because children of all abilities can generally access VR software given its intuitive nature [30]. It has been used successfully to enhance the learning of historical chronology. Learning about the passage of time and the correct sequencing of events is arguably an important part of understanding history generally. Time and space are clearly closely related – we might say that the distance between two locations is 4 kilometers or alternatively 20 minutes' walk. Historical timelines can be set up as spatial displays. By setting up a timeline like a row of shops, it is possible to represent successive events in history as individual items (each a "shop frontage") and these can be remembered in sequence just as we might remember a row of shops [31, 32]. This has proved beneficial compared with learning from booklets or equivalent PowerPoint displays when the design of the environment is appropriate, and suitable for the age of the child [33, 34].

Moderating variables

VR is arguably a sensitive means of investigating subtle influences on behaviours, including sex differences in information processing [35], and especially anxiety effects on spatial behaviours (see [36]). In research just published, Schoenfeld et al. [37] have found that when adult participants with ages ranging from 20-80 years were tested in a sophisticated virtual version of the familiar Water Maze, age was a major predictor of spatial performance, although this was moderated by depression and anxiety scores, while personality traits (particularly Extraversion) predicted weaker spatial perseveration. VR has been used to assess human behaviours in situations such as mazes originally designed for animals [38], and can enable direct comparisons of animal and human performance [39].

Are there drawbacks to using VR?

Students with learning difficulties have been trained in a VE to take a bus route to their college or workplace, getting on and off the bus at the appropriate points and identifying significant landmarks en route and guides to their progress and location. In that case the training was successful. VR training has proved useful in training road crossing skills in children, including children with cognitive challenges [40, 41]. However, although children with autistic spectrum disorders have been trained to identify safe intervals between cars when crossing a busy road, this raised concerns that a child who is somewhat "detached" from reality, they might, after VR training, subsequently fail to distinguish virtual from real and may attempt dangerous road crossings as a result.

Darken and Silbert [42] argued that long periods of exposure were needed to become familiar with an environment in VR, although others have found short periods to be adequate even when using unsophisticated technology such as desk-top VR presentation (e.g., [2, 43, 44]. It should be noted that desk-top presentation is often the medium of choice, given that end users of VR systems are likely to be schools, hospitals and individuals, many unable to afford the luxury of head-immersion and other hardware.

What are the future potential applications?

There are many. Future applications of VEs are dependent upon our better understanding of the way in which the brain processes information from VEs compared to reality. Also, VR may have been held back in the past by the fact that no universal software has been available. In the 1980s and 90's, easy-to-use packages such as SuperScape, easily programmable with draw-down menus, were generally available at a low cost and with support from the company. Many universities adopted SuperScape for its VR research. However, SuperScape withdrew from the academic market, lured by Japanese and American applications in architecture and modelling. Thus some of the anticipated benefits of VEs have never materialized. Applications of VEs must be cost-effective and so for small projects such as on-line visits by potential buyers to houses which they cannot easily visit; this is only cost-effective if the building is very expensive. On the other hand, VEs have been used in industry; motor companies now design vehicles in virtual form before putting them on the production line; totally authentic virtual engines can be modelled and used to give designers and mechanics the most intimate understanding of their working parts and spatial relationships among components as they (virtually) operate. Safety training in buildings, virtual building evacuations, and real-time virtual evacuations from aircraft have all been used, and in a situation that can be anxiety provoking but without asking participants to adopt any real risk. Aircraft evacuation is a good example of the need for better understanding of spatial cognition in virtual and real environments and transfer between the two. Clearly, evacuation from an aircraft is likely to occur in darkness, and underestimation of virtual distances [45], for example between doors and safety equipment, could be crucial. Other applications such as fire fighter training, military training [46], integration of team responses to emergencies, and 3-D training of surgeons using game-like environments [47] have all been used successfully, and again benefit from understanding of the spatial cognitive factors involved. There are many clinical applications (see [48–52], the most successful of which has been the treatment of neurotic disorders such as agoraphobia [53, 54]. VR has been shown to have adjunctive benefits to exercise in stress management [55].

Virtual museums have been created, an application that points up both the limitations and the benefits of VR usage. On one hand, it is unlikely that, even in a future populated by individuals who have grown up surrounded by technological media, VR will effectively or acceptably replace the experience of visiting an actual museum. Nevertheless, it could be especially useful where virtual artefacts cannot usually be investigated at close quarters or handled; studies have used datagloves to allow the manipulation of virtual objects that would usually be viewed from behind glass cases. Various forms of augmented reality become possible, limited only by our imagination.

Conclusions

VET has brought a range of benefits, and has great potential for future development. Although there are issues to be considered when using VEs, it can generally be concluded that information acquisition from VE simulations is reliable and authentic, equivalent to that gained from experience within real environments. Assuming that VE technology remains affordable, there are likely to be many important future applications, in situations where training in reality is dangerous, where real spatial environmental cues cannot be easily manipulated and varied, and where the augmentation of real experience is beneficial.

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Nigel Foreman – BSc (Bradford), PhD (Nottingham), Hon. Doc (Novi Sad), is Professor emeritus in Psychology at Middlesex University, London, UK. He has over 200 publications in international books and journals and has held over £1.5 million in research grants. He was the Chair of the International Committee of the British Psychological Society (BPS) for 8 years and sat on several other Boards and Committees, including the BPS Council, Ethics Committee, President's Award and Lifelong Achievement Award Committees. He led a delegation of international psychologists to China and Vietnam in 2004. He has represented BPS on the Scientific Affairs Board of the European Federation of Psychologists Associations (EFPA) and chaired the Board between 2007 and 2012. He has held the post of Professor in Psychology in Saint Petersburg University, Russia, and holds an Honorary Doctorate from the University of Novi Sad, Serbia. He has supervised student exchanges between the UK and America, Russia, Serbia, Macedonia and The Czech Republic, and arranged publishing contracts between the BPS and Russian publishers. Nigel's established contacts with influential academics across the world and his high reputation allows him of giving authoritative advice on commercial exchanges, also educational exchanges and integration, across Europe, Russia and beyond.

Найджел Форман – BSc (Bradford), PhD (Nottingham), Hon. Doc (Novi Sad). Удостоен степени почетного профессора психологии Миддлсекского университета. Результаты его исследовательской деятельности активно публикуются в научных периодических изданиях, а также в образовательных пособиях. Его деятельность активно поддерживалась академическими и государственными сообществами в виде грантов на исследования, которые суммарно составили 1,5 миллионами фунтов стерлингов. В течение 8 лет он занимал пост председателя Международного комитета Британского психологического общества и являлся членом нескольких других советов и комитетов, включая Совет Британского психологического общества, Комитет по этике, комитеты Премии премьер-министра и Премии «За дело всей жизни». Он был главой международной делегации психологов в Китае и Вьетнаме в 2004 г., а также представлял Британское психологическое общество в Ученом совете Европейской федерации ассоциаций психологов и председательствовал в Совете с 2007 по 2012 гг. Он занимал пост профессора психологии в Санкт-Петербургском университете в России, имеет почетную докторскую степень университета г. Нови Сад, Сербия. Он выступал в качестве инспектора при обмене студентами между Великобританией и США, Россией, Сербией, Македонией и Чешской Республикой, а также обеспечил заключение издательских договоров между Британским психологическим обществом и российскими издателями. Профессиональные контакты Найджела с влиятельными академиками по всему миру и его высокая репутация позволяет ему давать авторитетные советы по вопросам коммерческого обмена, образовательного обмена (обмена студентами) и научно-исследовательской интеграции между академическими центрами по всему миру.

Liliya Korallo – PhD, Practitioner Psychologist, Chartered Psychologist, Cognitive Behavioural Therapist, has been an active contributor to educational activities in the UK for the last 15 years. She has graduated from Middlesex University and University College in London (UCL). Liliya has completed her PhD entitled “The use of Virtual Environments in the teaching of historical chronology”. Her research has been financed by the Leverhulme Trust and Halle University, Germany; her findings have been published in international peer-reviewed journals (Instructional Science, Journal of Virtual Reality, Computers and Education and many others). Moreover, her papers have been presented at international and national conferences in Great Britain, Vietnam, Germany, Greece, the USA, Norway, Sweden, Serbia, Ukraine and Turkey. In June 2012 her research received a high accolade from such authoritative editions as the Times Educational Supplement and The Psychologist. She has just contributed a chapter to an influential book "On Human Visualization", which is due to be published by the leading Springer publishing house. Liliya has been collaborating on projects with Germany (“Use of VEs in clinical psychology”), Croatia (“Invited young academics to the UK”), Vietnam (“Culture and mental health”), Slovenia, and Ukraine (Integration of the Ukrainian Psychological Society into EFPA). She is constantly been invited as a reviewer for different S&R projects of West Europe.

Лилия Коралло – PhD. Научный сотрудник, психолог, Миддлсекский университет. Практикующий психолог высшей квалификации, специалист в области терапии когнитивных и поведенческих нарушений. На протяжении последних 15 лет Лилия активно занимается образовательной деятельностью в Великобритании. Она окончила Миддлсекский университет и Университетский колледж в Лондоне. Лилия защитила кандидатскую диссертацию на тему «Использование виртуального пространства при изучении исторической хронологии». Ее работы финансировались Фондом Leverhulme и Университетом Галле (Германия); результаты ее экспериментов были широко освещены международными рецензируемыми журналами: Instructional Science, Journal of Virtual Reality, Computers and Education и многими другими. Помимо этого, результаты ее исследований были представлены на многочисленных международных и национальных конференциях в Великобритании, Вьетнаме, Германии, Греции, Норвегии, Сербии, США, Турции и Украине. В июне 2012 исследования д-ра Коралло получили высокую оценку таких авторитетных изданий, как Times Educational Supplement и The Psychologist. Она является соавтором книги «О зрительном восприятии человека», опубликованной ведущим издательством Springer. Г-жу Коралло регулярно приглашают в качестве эксперта в различные научно-исследовательские проекты Западной Европы.

Nigel Foreman – BSc (Bradford), PhD (Nottingham), Hon. Doc (Novi Sad), Emeritus Professor, Middlesex University, London, NW4 4BT, UK; International Laboratory of Neurophysiology of Virtual Reality, ITMO University, Saint Petersburg, 197101, Russian Federation; n.foreman@mdx.ac.uk

Liliya Korallo – PhD, Practitioner Psychologist, Chartered Psychologist, Cognitive Behavioural Therapist, Psychologist, Middlesex University, London, NW4 4BT, UK; International Laboratory of Neurophysiology of Virtual Reality, ITMO University, Saint Petersburg, 197101 Russian Federation; lkorallo@yahoo.co.uk

Найджел Фореман – доктор наук, профессор, почетный профессор, Миддлсекский университет, NW4 4BT, Лондон, Великобритания; Университет ИТМО, Санкт-Петербург, 197101, Российская Федерация; n.foreman@mdx.ac.uk

Лилия Коралло – PhD, научный сотрудник, психолог, Миддлсекский университет, Лондон, NW4 4BT, Великобритания; Университет ИТМО, Санкт-Петербург, 197101, Российская Федерация;lkorallo@yahoo.co.uk

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