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Editorial

Gamification: What It Is and Why It Matters to Digital Health Behavior Change Developers

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Abstract

This editorial provides a behavioral science view on gamification and health behavior change, describes its principles and mechanisms, and reviews some of the evidence for its efficacy. Furthermore, this editorial explores the relation between gamification and behavior change frameworks used in the health sciences and shows how gamification principles are closely related to principles that have been proven to work in health behavior change technology. Finally, this editorial provides criteria that can be used to assess when gamification provides a potentially promising framework for digital health interventions.

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KEYWORDS

behavioral medicine; behaviour and behavior mechanisms; behavioral research; behavioral sciences; persuasive communication; health psychology; psychology; experimental game; interactive games; computer games

Introduction

Although health behavior change research suggests that it is easy to influence how people think and behave, practitioners who have worked in the health behavior change field, with populations or individuals, will often complain that that behavior change is difficult to achieve, expensive, and impacts are often short-lived.

The average public health campaign is able to impact the behavior of roughly 5% of a population [1], while a meta-analysis that I co-investigated a few years ago showed that online behavior change technologies could impact the behavior of roughly 10% of their users [2](this figure was derived by comparing a Pearson's coefficient effect size to a percentage, as used by Snyder (2007); however, this method is subject to significant statistical bias [3] and should therefore only be taken as a ballpark figure at best). Given the modest impacts from evidence-based interventions, why are we now witnessing widespread claims that gamification makes it easy to shape how people think and behave, simply by rewarding users with points and badges? Is gamification really a magic solution to shaping behavior, or simply, unrealistic hype?

In this editorial, I describe and evaluate gamification, address misconceptions, show linkages to health behavior change theory, and advocate when gamification is a good or bad approach for digital health behavior change interventions.

Hype Around Gamification

At present, there is no shortage of gamification advocates who claim badges, points, and competition will get everyone so hooked on digital technologies, that developers should gamify their interventions immediately, or get left behind. However, jumping on this gamification bandwagon is a risky undertaking. Not because gamification does not work, but rather, because it is easy to get it wrong if developers do not understand what it is, know its limits, and make informed decisions on its application. Gamification is just one of many persuasive architectures. However, like all other persuasive design patterns, gamification has merit when used in the right way, under the right circumstances.

The Active Ingredients of Gamification

Gamification is defined as the use of game design elements in non-game contexts [4]. The idea is that if we can isolate the

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active ingredients that make games addictive, then intervention developers can put those ingredients into their digital technologies and make them addictive too. For instance, we can make a routine non-game activity, such as taking medication, into a game that is fun and engaging by adding game elements, such as earning points for taking medications.

To apply gamification, developers first need a list of game design elements, and then second, they need to integrate these elements into their intervention. However, the problem is that gamification researchers do not always agree on what these ingredients are, and some researchers take the position that these ingredients cannot even be named.

Within this debate, I take the view that technology is only persuasive when it employs specific behavior change ingredients, as one of the key principles of evidence based behavioral medicine [5-7]. These persuasive ingredients are the factors that exert persuasive force on people, encouraging them to shift their beliefs, attitudes, and actions. If these ingredients are removed, the technology is no longer persuasive. In the sciences, these ingredients have different names, but I will refer to them as "behavior change strategies", "persuasive strategies", or simply, "strategies".

To identify these gamification strategies, I reviewed a number of popular gamification taxonomies from academic and non-academic sources by Charles Coonradt [8], Reeves and Read [9], Gabe Zichermann [10], and Marc Prensky [11]. I identified the common strategies listed by these authors, and compared them to a taxonomy of interactive behavior change and persuasive design strategies within my Persuasive Communication Model [12].

After, I identified 7 core ingredients of gamification that have clear linkages to proven behavior change strategies, with the exception of fun and playfulness, which has perhaps, not received much attention in the health behavior change literature. These 7 ingredients of gamification are listed in Textbox 1.

My goal was to identify the persuasive architecture of gamification, the essential strategies that combine to produce an effect greater than the sum of its parts. Put another way, the persuasive architecture of gamification is the combination of ingredients that make a product fun and engaging. Take away some of these core ingredients, and the product becomes dull. Add them back in, and the magic happens. A persuasive architecture is the optimal blend of persuasive strategies for a particular application [2].

Whereas the strategies in Textbox 1 are the broad principles that make gamification addictive, the gamification mechanics (or tactics) are the on-screen features that users interact with. For instance, the strategy of motivating a user by *comparing their progress with others* can be implemented with the gamification tactic of *showing the game leaders*. Textbox 2 shows 10 of the most popular gamification tactics [13].

One of the chief misconceptions about gamification is that any technology that employs game tactics will be more engaging. The problem with this thinking is that it mistakes superficial game tactics for deeper psychological strategies. For instance, it is risky to believe that badges will motivate users, without considering the persuasive strategies that the game tactics must satisfy, where a badge's value comes from a community that places value on that badge, and where the badge's value is further dependent on whether it transfers anything of value to the person. Offering game tactics that do not satisfy persuasive strategies is like cooking dinner for someone with ingredients (game tactics) they do not like (strategies).

Textbox 1. The persuasive architecture of gamification and its 7 persuasive strategies.

1. Goal setting: Committing to achieve a goal
2. Capacity to overcome challenges: Growth, learning, and development
3. Providing feedback on performance: Receiving constant feedback through the experience
4. Reinforcement: Gaining rewards, avoiding punishments
5. Compare progress: Monitoring progress with self and others
6. Social connectivity: Interacting with other people
7. Fun and playfulness: Paying out an alternative reality

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Textbox 2. Popular gamification tactics.

1. Providing clear goals
2. Offering a challenge
3. Using levels (incremental challenges)
4. Allocating points
5. Showing progress
6. Providing feedback
7. Giving rewards
8. Providing badges for achievements
9. Showing the game leaders
10. Giving a story or theme

The Efficacy of Gamification

Overview

In order for gamification to be considered effective, gamified technology must outperform other design patterns, in terms of its ability to influence people's beliefs, attitudes, or behaviors. Moreover, to be considered effective, gamification must sustain these impacts over the long-term, and offer more than a short-term novelty effect.

However, the question that is rarely asked is whether there is evidence that shows gamification can influence how people think or behave? To answer this question, there are perhaps four stream of evidence that we can draw from. They include (1) anecdotal evidence, (2) research on the efficacy of gamification, (3) ingredients that have been proven to work, and (4) persuasive architecture that is related to proven theories.

Anecdotal Evidence

Much of the hype around gamification seems to come from ad hoc anecdotal evidence, in the form of case studies and industry claims. Although highly unreliable, this body of ad hoc success stories has served to raise awareness of gamification concepts, and prompted researchers to take a closer look at gamification.

Research on the Efficacy of Gamification

As research on gamification started to appear just before 2010, we recently reached the point where there were enough quality academic studies, that a team of researchers conducted a systematic review of the scientific literature [13]. In their publication, "Does Gamification Work?", the research team found evidence across numerous studies, that gamification can influence psychological and physical outcomes, meaning gamification can make a digital product more fun and engaging.

However, not all studies showed positive effects, and the impact seemed to vary according to the community, users, and product, with some users complaining that gamification was annoying. Additionally, there were far more studies in particular contexts, such as online learning, intra-organizational systems, and work environments, with the lack of studies from other domains possibly signaling that gamification may only work in contexts that already share a common persuasive architecture. Finally, the researchers raised one red flag, as they could not tell if the reported outcomes represented sustainable long-term impacts, or just short-term novelty effects.

Ingredients That Have Been Proven to Work

From the point of view of evidence-based behavioral medicine, the only thing that would matter in gamification is whether it employs principles and tactics that have been scientifically proven to influence health outcomes.

To quickly assess the link between gamification and health behavior change, I conducted an exploratory comparison of the 7 ingredients of gamification to behavioral science principles that have been proven to work in digital health behavior change interventions, drawing on validated principles from my prior meta-analysis on the factors that make health behavior change technologies work [2].

I mapped 27 techniques and principles to the 7 gamification strategies. Table 1 shows the top two most effective and statistically significant behavior change principle and techniques.

This exploratory mapping demonstrates that there are some promising links between gamification principles and digital health behavior change science, with one gap that stood out, being no strong link to fun and playfulness in health behavior change approaches. Although gamification shows some clear links to health behavior change strategies and tactics, the technical mechanics used in health behavior change interventions can be radically different than those used in gamified technologies, even though they may appeal to similar psychological faculties.

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Table 1. Gamification strategies and validated behavior change ingredients.

Gamification strategies	Validated behavior change ingredients [2]
1. Goal setting	• Agree behavioral contract • Goal setting (behavior)
2. Capacity to overcome challenges	• Time management • Action planning
3. Providing feedback on performance	• Prompt self-monitoring of behavioral outcome • Prompt self-monitoring of behavior
4. Reinforcement	• Provide rewards contingent on successful behavior
5. Compare progress	• Prompt self-monitoring of behavioral outcome • Provide normative information about others' behavior
6. Social connectivity	• Social influences (norms) • Plan social support/social change
7. Fun and playfulness	N/A

Persuasive Architecture That is Related to Proven Theories

Beyond the direct empirical evidence, there is also theoretical support for gamification, as a framework that shares many strategies in common with other theories that have been proven to work in the health field.

The persuasive architecture of gamification shares elements in common with coaching, which relies on a coach's ability to foster team member motivation, employ strategies to help their team overcome opposition, provide support in building member's techniques, and help members build their character [14]. The architecture of gamification is also extremely close to the cybernetic variations of self-regulation theory, based on feedback loops, which cover all strategies except perhaps, social connectivity, and fun and playfulness [15]. Although gamification shares the same strategies, there are big differences in the tactical way that these strategies are implemented. However, the similarity does mean that it is easier to gamify digital interventions modeled on coaching or self-regulation theory, because they are already quite similar.

One of the theories that is infrequently used in the health field, but popular among video game designers, is *flow*, the study of how people become absorbed and engaged in an activity when they are doing something where their skill level is perfectly matched to the challenge level [16]. According to the principle of flow, if a game is too difficult, people will become stressed and stop playing. If a game is too easy, people will become bored and stop playing. But if the challenge keeps increasing as the person's skill increases, they will have a flow experience, become absorbed in the task at hand, and experience a meditative-like absorption in what they are doing. Bringing people to this state of mind is a key goal in game design.

Selecting the Right Persuasive Architecture for an Interventions

Although there is evidence that suggests gamification works, there are some major risks associated with the current gamification hype. The chief risk is becoming overconfident in the ability of gamification to exert massive influence across all contexts, which can cause developers to form tunnel vision and fixate on just one of many persuasive architectures.

Locking into one framework might cause developers to miss opportunities to identify the best architecture for the job. Every persuasive architecture has its own unique mix of ingredients, and suitability to particular users and contexts. For instance, a sign-up landing page, health screener, donation page, or social networking site all draw on different combinations of persuasive ingredients. Moreover, my recent research is showing that the world's most successful websites are hyper optimized, often offering more persuasive strategies per square inch than many of the less popular sites.

What matters in behavior change design is knowing which persuasive architecture is right for a particular application, and identifying when gamification, in whole or part, is suitable to a particular application.

Assessing the Suitability of Gamification

Intervention developers should only use gamification when it is suitable to a given audience-product mix. However, it is not easy to know in advance whether or not gamification makes sense for a particular project and its unique audience-intervention mix.

To evaluate if gamification is suitable to a particular intervention, Textbox 3 presents criteria that developers can use to evaluate when gamification offers a promising framework. However, users are the ultimate judges of intervention efficacy, so any gamified interventions will require user testing, to determine if they can work or not.

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Textbox 3. Criteria to consider when evaluating if gamification is suitable to a particular intervention.

1. The intervention users
2. The users' social context
3. The psychological and behavioral outcomes that are being pursued
4. How closely the intervention's logic model or theory of change fits with the persuasive architecture of gamification
5. The interactive product or platform that is being planned
6. The compatibility of the interactive product, users, and community with the 7 gamification strategies
7. The compatibility of the interactive product, users, and community with gamification tactics

Final Thoughts

There is promising evidence that suggests gamification works, and on the surface, gamification appears to share elements in common with proven health behavior change approaches. Given this, it is easy to see how existing digital interventions can borrow gamification principles, by considering flow, meaningful rewards, making them more social, and most importantly, finding innovative ways to make digital health interventions fun and engaging.

JMIR Serious Games is a new important journal devoted to research and opinion around games and gamification for behavior change and other applications, and as one of the editorial board members I look forward to help building the evidence base in this emerging area.

Conflicts of Interest

None declared.

References

1. Snyder LB. Health communication campaigns and their impact on behavior. J Nutr Educ Behav 2007;39(2 Suppl):S32-S40. [doi: 10.1016/j.jneb.2006.09.004] [Medline: 17336803]
2. Cugelman B, Thelwall M, Dawes P. Online interventions for social marketing health behavior change campaigns: a meta-analysis of psychological architectures and adherence factors. J Med Internet Res 2011;13(1):e17 [FREE Full text] [doi: 10.2196/jmir.1367] [Medline: 21320854]
3. Lipsey M, Wilson D. Practical meta-analysis. Thousand Oaks, Calif: Sage; 2001.
4. Deterding S, Dixon D, Khaled R, Nacke L. From game design elements to gamefulness: Defining gamification. In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments.: Envisioning Future Media Environments; 2011 Presented at: MindTrek 11; 28-30 September 2011; Tampere, Finland.
5. Embry DD, Biglan A. Evidence-based kernels: fundamental units of behavioral influence. Clin Child Fam Psychol Rev 2008 Sep;11(3):75-113 [FREE Full text] [doi: 10.1007/s10567-008-0036-x] [Medline: 18712600]
6. Michie S, Johnston M, Abraham C, Lawton R, Parker D, Walker A. Making psychological theory useful for implementing evidence based practice: a consensus approach. Qual Saf Health Care 2005 Feb;14(1):26-33 [FREE Full text] [doi: 10.1136/qshc.2004.011155] [Medline: 15692000]
7. Davidson KW, Goldstein M, Kaplan RM, Kaufmann PG, Knatterud GL, Orleans CT, et al. Evidence-based behavioral medicine: what is it and how do we achieve it? Ann Behav Med 2003 Dec;26(3):161-171. [doi: 10.1136/qshc.2004.011155] [Medline: 14644692]
8. Coonradt CA. The Game of Work. Layton, Utah: Gibbs Smith; 2007.
9. Reeves B, Read J L. 2010. Ten ingredients of great games URL: http://www.cedma-europe.org/newsletter%20articles/misc/Ten%20Ingredients%20of%20Great%20Games%20(Apr%2010).pdf [accessed 2013-11-26] [WebCite Cache ID 6LQaqKH16]
10. Zichermann G. 2011. The six rules of gamification cited 2013 5 Nov 2013; URL: http://www.gamification.co/2011/11/29/the-six-rules-of-gamification/ [accessed 2013-11-26] [WebCite Cache ID 6LQb7JCpU]
11. Prensky M. Fun, play and games: What makes games engaging. In: Digital game-based learning. New York: McGraw-Hill; 2001.
12. Cugelman B. Persuasive design toolkit. Toronto, Canada: AlterSpark Corp; 2013.
13. Hamari J, Koivisto J, Sarsa H. Does gamification work? - a literature review of empirical studies on gamification (forthcoming). 2014 Presented at: 47th Hawaii International Conference on System Sciences; January 6-9, 2014; Hawaii, USA.
14. Kavussanu M, Boardley ID, Jutkiewicz N, Vincent S, Ring C. Coaching efficacy and coaching effectiveness: Examining their predictors and comparing coaches' and athletes' reports. The Sport Psychologist 2008;22(4):383-404.
15. Carver C, Scheier M. On the structure of behavioral self-regulation. In: Boekaerts M, Pintrich PR, Zeidner M, editors. Handbook of self-regulation. San Diego, Calif: Elsevier Academic Press; 2005:41-84.

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16. Csikszentmihalyi M. Flow: The Psychology of Optimal Experience. New York, USA: Harper Perennial Modern Classics; 2008.

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Original Paper

Surgical Trainee Opinions in the United Kingdom Regarding a Three-Dimensional Virtual Mentoring Environment (MentorSL) in Second Life: Pilot Study

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Abstract

Background: Medical mentoring is becoming increasingly complex with the evolving needs of trainees and the complexities of their personal and social lives. The Internet is an enabling technology, which increasingly facilitates interaction with multiple people at a distance. Web 2.0 and 3.0 technology shows promise in furthering this facilitation.

Objective: The objective of our study was to establish opinions among doctors in postgraduate surgical training regarding mentoring and whether these doctors would readily accept virtual mentoring following a brief experience.

Methods: On the 12th of February 2012, an introductory teaching class was arranged by The London Postgraduate School of Surgery for doctors in training. Participants were introduced to a novel virtual mentoring system and asked to complete a questionnaire regarding their opinions before and after the demonstration.

Results: A total of 57 junior doctors attended. Among them, 35 completed questionnaires pre- and postdemonstration. Regarding usefulness of a 3D virtual environment for mentoring, 6/35 (17%) agreed or strongly agreed and 20/35 (57%) were unsure prior to the session. Following 20 minutes using MentorSL, this significantly increased to 14/35 (40%) agreeing or strongly agreeing with 11/35 (31%) unsure (P<.001). Prior to using MentorSL, regarding usefulness of voice communication for virtual mentoring, 11/35 (31%) agreed or strongly agreed and 18/35 (51%) were unsure. Following 20 minutes using MentorSL, 19/35 (54%) agreed or strongly agreed and 10/35 (29%) were unsure of usefulness. Regarding ease of use of navigation, search mentor, meeting scheduling, and voice communication features, 17/35 (49%), 13/35 (37%), 15/35 (43%), and 16/35 (46%) participants agreed or strongly agreed, respectively. Regarding usefulness of telementoring, 24/35 (69%) agreed or strongly agreed, increasing to 28/35 (80%) following the introduction. For usefulness of multiple mentors, initially 24/35 (69%) agreed or strongly agreed increasing to 29/35 (83%). For overall satisfaction, 30/35 (86%) reported good or adequate and 19/35 (54%) agreed or strongly agreed with using the system again.

Conclusions: These data suggest that a short introduction on how to use virtual systems may result in significant participation and use of virtual mentoring systems.

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KEYWORDS

education; Internet; training

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Introduction

Background

Doctors in postgraduate surgical training often require guidance to overcome hurdles associated with modern-day surgical training. Good mentoring delivered in a timely fashion is a way in which surgical trainees may be helped through these difficulties in a manner compatible with the principles of adult learning.

The Standing Conference on Postgraduate Medical and Dental Education (SCOPME) in the United Kingdom, describes mentoring as:

> *The process whereby an experienced, highly regarded, empathic person (the mentor) guides another individual (the mentee) in the development and re-examination of their own ideas, learning, and personal and professional development. The mentor, who may or may not work in the same organization or field as the mentee, achieves this by listening and talking in confidence to the mentee [1]*

The mentors have many roles that have previously been reviewed [2]. Briefly, these include advisor, coach, counselor/guide, and role model. As someone who has successfully negotiated some of these difficulties, a mentor may offer motivation, hope, and advice for the mentee. As technology increasingly becomes part of a managed learning process, expert mentoring of trainees, facilitated by technology, may become essential for ensuring patient safety.

It has been previously reported that trainees often do not have mentors or are unaware of the role of the mentor and therefore do not have beneficial meetings with them [2,3]. The management concept "Just-in-time" was popularized by the Toyota Motor Company and resulted in huge increases in efficiency and productivity. The essence of the system is to respond to needs and only call upon resources when they are required [4]. A parallel may be drawn with mentoring in that it is potentially a labor-intensive and costly resource, which is not necessarily required at all times. Mentoring may be best achieved in a "just-in-time" fashion where an appropriate mentor is available to facilitate problem solving in response to a real-world need. In order for this mentoring to be achieved in a comfortable learning environment, a knowledgeable, yet not necessarily proximate mentor may be most suitable.

World Wide Web

The latest digital technologies may be a key enabler to support these requirements. The Department of Health in the United Kingdom has recently published a "Framework for Technology Enhanced Learning" that advocates the use of e-learning and simulation to enhance learning where there is a clear benefit to patient care [5]. Internet-based technology developments, including the World Wide Web (WWW), allow for increasing interactivity and may be of use in fulfilling tele- and multiple-mentoring needs. Improved mentoring may lead to improved trainee development, which may lead to improved patient care. There has been an evolution of the ways that interaction is facilitated and information processed and retrieved in the WWW [6]. Today's WWW provides for an immersive, interactive, and information-rich potential resource. e-mentoring has been shown to be efficacious in the context of North American school children, interestingly reporting that the frequency of mentor-mentee interaction moderates the relationship between mentee "self-efficacy" and previous Internet experience with positive outcome [7]. The Web 3.0 format encompasses virtual worlds, the semantic Web, microformats, natural language search, data mining, machine learning, recommendation agents, artificial intelligence, and augmented reality technologies. Augmented reality involves a fusion of the physical world and computer-generated content, potentially delivered through the Internet. The use of augmented reality for anatomy education has been demonstrated [8], and there is great potential for this technology.

MentorSL

Virtual worlds including Second Life (SL) by Linden Laboratories [9] and Olive by Forterra Systems [10] provide content as a three-dimensional (3D) environment in which we can navigate and interact with others as virtual representations of ourselves, avatars. Second Life, currently the most popular virtual world, facilitates streaming audio/video/TV/YouTube collections, 3D virtual libraries, and virtual tourist attractions and destinations [11]. A virtual emergency department training study has reported that ease of use and limited access to the software were identified as barriers to adoption [12]. Meskó summarized educational applications' uses of SL [13]. He discussed potential advantages as being global collaboration without boundaries; interactivity in a manner better than a videoconference with use of videos, presentations, images, and Web links at the same time in one place. Being able to draw from a worldwide pool of experts and having the ability to establish exhibits which are not possible via a videoconference [14] or a website are also cited as advantages [15,16]. Interactions between SL residents may benefit each others' participation via networks that allow for dynamic, evolving systems all made possible by "semantic" Web technology [17]. Virtual reality resources have been successfully used as educational resources [18-27].

For the purposes of exploring new methods to support mentoring, a 3D virtual system, MentorSL, was developed [28]. Avatars assemble in a registration area, where they have a range of mentoring databases available to them (Figure 1). Mentors are able to log on to SL as avatars and provide mentoring, through virtual world communication, to their mentees. A range of online mentoring resources is available to both mentors and mentees and there are links to other mentoring resources.

Doctors in postgraduate surgical training in the London Postgraduate School of Surgery (see Textbox 1) were invited to experience the system and submit their views. The primary aims of our study were to establish whether barriers existed to the adoption of the 3D virtual mentoring environment and to establish whether a short introduction would be sufficient to achieve participant "buy-in". The secondary aims were to establish which aspects of the system were deemed most useful and which further aspects should be developed further.

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Textbox 1. Doctors in postgraduate surgical training.

The London Postgraduate School of Surgery is the largest surgical training organization in the world. It is responsible for managing more than 900 trainees. The school offers programs at prestigious teaching centers across the capital city. Doctors in postgraduate training spend an initial 2 years (FY1, FY2) in generic foundation training; this is followed by a further 2 years (CT1, CT2) in core surgical training. Successful competitive progression results in spending an additional 6 years in specialty surgical training (ST3 to ST8) toward award of completion of training.

Figure 1. Photograph from Second Life showing the MentorSL meeting complex. Licensed under Creative Commons Attribution 2.0.



Methods

Study Participants

Doctors in postgraduate surgical training were invited to attend a "taster" session introducing virtual mentoring via the online virtual world SL at the London Postgraduate School of Surgery, UK. This session was a subsection of a wider training meeting being held. The trainees were within the first four years of postgraduate training. All participants had previously experience of mentoring as a component of "Foundation Training" which includes appointing of an "Assigned Educational Supervisor" by the training program. A 10-minute presentation on SL and specifically on MentorSL including an "in-world" walk through was given via a large screen projector. SL as a virtual world facilitating interaction of virtual people or avatars was explained. Methods used to navigating and communicate in SL were explained to participants. MentorSL was introduced as a tool to facilitate mentoring in the virtual world of SL. The search mentor facilities in MentorSL and the facilities to arrange and hold meeting within the MentorSL framework were explained and demonstrated. Following a short questions and answers session, participants were able to sit in groups at computer stations running Second Life fitted with multiple headsets. Facilitators in the real world as well as SL were available to help and guide participants.

Data Collection

Participants were invited to fill in an anonymous questionnaire regarding their perceptions both prior to and after the session. The questionnaire consisted of 7 domains: (A) demographic data, (B) perceptions regarding mentoring, (C) perceptions regarding the 3D Web, (D) perceptions regarding the practicalities of MentorSL, (E) perceptions regarding tele- and multiple mentoring, (F) perceptions regarding further enhancements in virtual mentoring, and (G) perceptions regarding future use of MentorSL (see Multimedia Appendix 1 for the questionnaire). These questions were determined with a view to establishing whether doctors in postgraduate surgical training would readily accept use of a virtual mentoring facility and whether any particular aspect of the facility was related to future use of the system. Demographic data were only collected once, questions in domains (B), (C), and (E) were posed both before and after participants spent 20 minutes using MentorSL. Questions in domains (D), (F), and (G) were only asked after participants spent 20 minutes using MentorSL.

Statistical Analysis

Statistical analysis was performed using SAS (Cary, USA). Data were presented as ratios and percentages. The chi-square test was used for significance testing.

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Results

Demographic Data

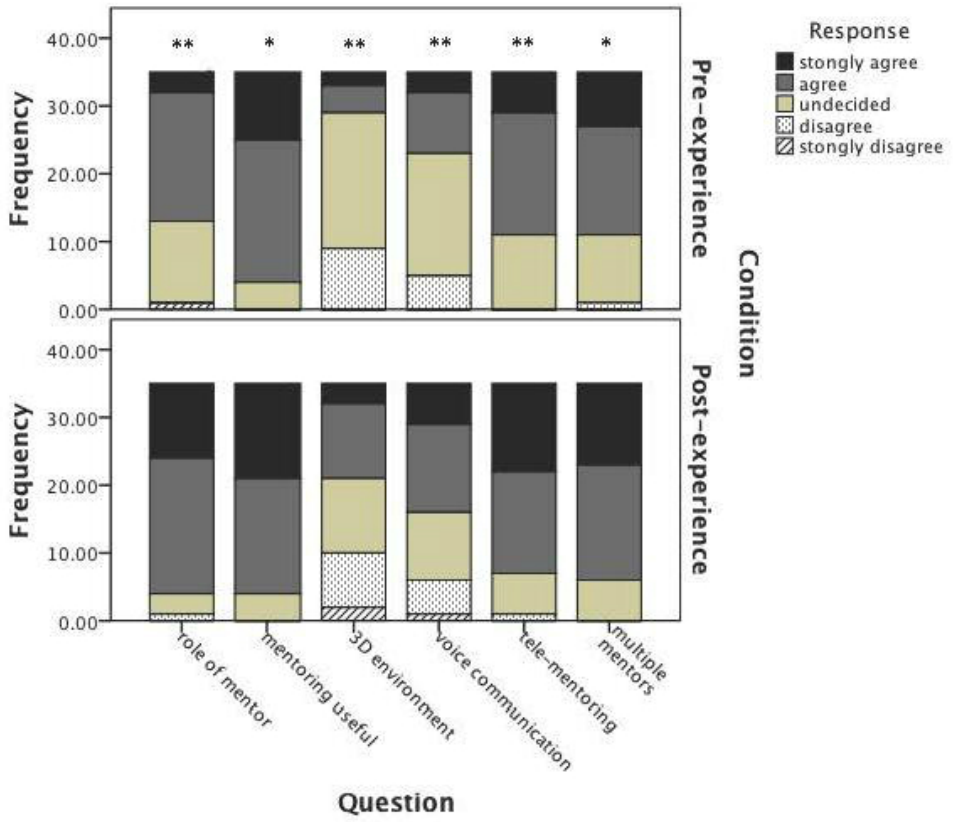
There were 57 participants in total, median age was 28.1 years (range 24-43). There were 32 females (32/57, 56%) and 25 males (25/57, 44%).

Of the total participants, 1/57 (2%) qualified in 2004, 3/57 (5%) qualified in 2007, 23/57 (40%) qualified in 2008, 13/57 (23%) qualified in 2009, and 17/57 (30%) qualified in 2011. Of the total participants, 20/57 (35%) were in foundation year 1 (FY1), 22/57 (39%) were in core surgical training 1 (CT1), and 15/57 (26%) were in core training 2 (CT2).

Of the 57 participants, 40/57 (70%) participants reported that they had firm plans for which specialty they would like to enter, 3/57 (5%) had no plans as yet, and 14/57 (25%) were unsure of their choice. The response rate for the questionnaire was 35/57 (61%).

In terms of previous experience with the 3D virtual environments, 6/57 (11%) had had previous experience and 51/57 (89%) had no experience or were unsure. Mentee perceptions are described below and summarized in Figure 2.

Figure 2. Stacked bar chart of response to questions pre- (above) and post-experience (below) of the MentorSL system. *Improvement in response; *P*<.05, **improvement of response; *P*<.001 (one-way chi-square test).



Perceptions Regarding Concepts of Mentoring

With regards to having understood of the roles of a mentor, prior to the experience, 3/35 (9%) said they strongly agreed, 19/35 (54%) said they agreed, 12/35 (34%) were unsure, and 1/35 (3%) strongly disagreed. Following the experience, there was a statistically significant improvement toward agreement (*P*<.001; chi-square test). Of 35 participants, 11/35 (31%) strongly agreed, 20/35 (57%) agreed, 3/35 (9%) were unsure, and 1/35 (3%) disagreed.

With regards to whether mentoring was thought to be useful, 10/35 (29%) strongly agreed, 21/35 (60%) agreed, and 4/35 (11%) were unsure. Following the experience, there was a statistically significant improvement toward agreement (*P*=.04; chi-square test). Of 35 participants, 14/35 (40%) strongly agreed, 17/35 (49%) agreed, and 4/35 (11%) were unsure.

Perceptions Regarding Mentoring via the 3D Web

When asked whether they thought whether a 3D virtual environment would be useful in mentoring prior to experiencing it, 2/35 (6%) strongly agreed, 4/35 (11%) agreed, 20/35 (57%) were unsure, and 9/35 (26%) disagreed. Following the experience, there was a statistically significant improvement toward agreement (*P*<.001; chi-square test). Of 35 participants, 3/35 (9%) strongly agreed, 11/35 (31%) agreed, 11/35 (31%) were unsure, 8/35 (23%) disagreed, and 2/35 (6%) strongly disagreed.

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Perceptions Regarding the Practicalities of MentorSL

Prior to experiencing MentorSL, when asked whether voice communication would be useful in the mentoring relationship, 3/35 (9%) strongly agreed, 9/35 (26%) agreed, 18/35 (51%) were unsure, and 5/35 (14%) disagreed. Following experiencing MentorSL, there was a statistically significant improvement toward agreement (P<.001; chi-square test). Of 35 participants, 6/35 (17%) strongly agreed, 13/35 (37%) agreed, 10/35 (29%) were unsure, 5/35 (14%) disagreed, and 1/35 (3%) strongly disagreed.

When asked regarding navigation in SL was sufficiently simple to use, 6/35 (17%) strongly agreed, 11/35 (31%) agreed, 14/35 (40%) were undecided, 2/35 (6%) disagreed, and 2/35 (6%) strongly disagreed.

When asked whether the search for mentor facility in MentorSL was sufficiently simple to use, 7/35 (20%) strongly agreed, 6/35 (17%) agreed, 19/35 (54%) were undecided, 2/35 (6%) disagreed, and 1/35(3%) strongly disagreed.

When asked whether the meeting scheduling facility in MentorSL was sufficiently simple to use, 4/35 (11%) strongly agreed, 11/35 (31%) agreed, 18/35(51%) were undecided, and 2/35 (6%) disagreed.

When asked regarding ease of using voice communication in SL, 6/35 (17%) strongly agreed, 10/35 (29%) agreed, and 19/35 (54%) were undecided.

Regarding overall satisfaction with MentorSL, 6/35 (17%) reported very good, 24/35 (69%) reported adequate, 4/35 (11%) reported slightly disappointing, and 1/35 (3%) reported very poor.

Perceptions Regarding Tele- and Multiple Mentoring

Regarding the usefulness of a specialist mentor who may be geographically remote, prior to the experience, 6/35 (19%) strongly agreed, 18/35 (51%) agreed, and 11/35 (31%) were unsure. Following the experience, there was a statistically significant improvement toward agreement (P<.001; chi-square test). Of 35 participants, 13/35 (37%) strongly agreed, 15/35 (43%) agreed, 6/35 (17%) were unsure, and 1/35 (3%) disagreed.

When asked regarding the perceived benefits of having multiple mentors available for specific mentoring needs, prior to the experience, 8/35 (23%) strongly agreed, 16/35 (46%) agreed, 10/35 (29%) were unsure, and 1/35 (3%) disagreed. Following the experience, there was a statistically significant improvement toward agreement (P=.002; chi-square test). Of the participants, 12/35 (34%) strongly agreed, 17/35 (49%) agreed, and 6/35 (19%) were unsure.

Perceptions Regarding Further Enhancement of Virtual Mentoring

When asked whether participants thought that real life facial recognition and animation of avatar facial features would be useful, 2/35 (6%) strongly agreed, 13/35 (37%) agreed, 13/35 (37%) were undecided, and 7/35 (20%) disagreed.

When asked whether hand gesture recognition and animation of avatar would be useful, 2/35 (6%) strongly agreed, 12/35 (34%) agreed, 14/35 (40%) were undecided, and 7/35 (20%) disagreed.

Perceptions Regarding Future Use of MentorSL

When asked whether participants would use MentorSL in the future, 4/35 (11%) strongly agreed, 15/35 (43%) agreed, 10/35 (29%) were undecided, 4/35 (11%) disagreed, and 2/35 (6%) strongly disagreed.

Discussion

Principal Findings

This study demonstrates that doctors in postgraduate surgical training are willing to “buy-in” to a virtual mentoring system in SL. The most well-received facilities were those of tele- and multiple mentoring and that of voice communication. The implication of these findings is that this mentoring system may be able to deliver mentoring to this group of doctors in a manner commensurate with their needs.

The response rate of 61% (35/57) in this study, seemingly low and a limitation of the study, is commensurate with other studies in this population [29]. We would suggest that a subsequent usability study would result in increased participant involvement and perceived benefit. Thus, we would suggest that this would be the lower limit of what a future usability study would engender. This study is not able to inform on the potential benefit of virtual mentoring using this system, and further work will be needed to establish this.

Perceptions

It the context of team training for triage of mass casualties, it has been demonstrated that trainees quickly adapt to a virtual environment and find it an experience that is beneficial to their professional development [30].

Despite the all-pervasive nature of the Internet in today’s society, 89% (51/57) of participants had no significant previous experience of 3D Web 3.0 technology. Despite this, we found that only 17% (6/35) of participants disagreed or strongly disagreed, following a short introduction, with using the system in the future.

Central to the provision of a virtual “just-in-time” mentoring system is the mentee perceiving the need for being mentored. At outset, only 21/35 (60%) participants agreed or strongly agreed that they understood the concept of mentoring; this improved to 31/35 (89%). In addition, the initial high agreement with the usefulness of mentoring was maintained following the introduction (31 predemonstration vs 32 postdemonstration).

The specific use of the 3D virtual world for mentoring is perhaps the most contentious issue to be assessed in the confines of a short introduction. More formed decisions will most likely require the on-going usage of the system by mentees. This seems to be reflected in that 14/35 (40%) were positive regarding the system, and 11/35 (31%) were unsure.

Importantly, the more immediate and apparent facilitatory benefits of the system seemed to be well received by the participants. This was reflected by the strong performance in the voice communication, tele-, and multiple-mentoring

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domains. Indeed, the voice communication domain showed a large increase in agreement from 4/35 (11%) to 16/35 (46%). The user-friendliness of the voice communication was found to have a major impact in acceptance of a SL training program for nurses [24].

There may be barriers to the adoption of these new technologies for medical mentoring. Hansen et al recalled Roger's diffusion of innovation theory in explaining attributes of a new technology affecting an individual's decision to adopt [31]. These attributes include the relative advantage of the innovation over the idea it supersedes, how the innovation meets the needs of potential adopters, how difficult the innovation is to understand and use, how the innovation may be tested in a timely fashion, and how outcomes associated with the innovation are visible to others. Interestingly, a study investigating these factors in adoption of e-mentoring by Greek mentors reported that only relative advantage was a significant factor in adoption [32]. Other potential drivers for adoption that may be important to further work are alluded to by the "Uses and Gratification" theory [33], suggesting that various forms of gratification affect utility. The well-established "Technology Acceptance Model" emphasizes "perceived usefulness" and "perceived ease-of-use" as important factors in new technology adoption [34], and these also may be important domains to investigate in future work.

With regards to future developments in the MentorSL, equivalent numbers were positive regarding animation of the avatars facial features and hand gestures to improve the experience.

Conclusions

We have demonstrated that the MentorSL system has the potential to be well accepted by mentees. This may be a reflection of the rapidly acquired understanding of the role of a mentor and the feeling of need for mentoring. Junior surgical trainees are able to rapidly familiarize with this novel communication modality and seem interested in further expansion of the virtual mentoring experience using facial and gesture recognition and avatar animation technology. Further work is required to evaluate utilization of this virtual mentoring facility when made available to doctors in postgraduate surgical training and to establish benefit. We are currently establishing a pilot study to trial medical mentoring using MentorSL in a cohort of surgical trainees in the London Postgraduate School of Surgery.

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Authors' Contributions

UJ conceived the idea, helped develop the software, and wrote the manuscript. NS is guarantor, and critically appraised the design and manuscript. NWJ critically appraised the manuscript and was involved with design.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Questionnaire.

[PDF File (Adobe PDF File), 54KB - games_v1i2e2_app1.pdf]

References

1. SCOPME. Supporting Doctors and Dentists at Work: An Inquiry into Mentoring. London: Standing Committee on Postgraduate Medical and Dental Education; 1998.
2. Jaffer U, Pennell A, Musonda P. General surgical trainee experiences of mentoring: a UK regional audit. J Surg Educ 2010;67(1):19-24. [doi: 10.1016/j.jsurg.2009.10.004] [Medline: 20421085]
3. Kaderli R, Muff B, Stefenelli U, Businger A. Female surgeons' mentoring experiences and success in an academic career in Switzerland. Swiss Med Wkly 2011;141:w13233 [FREE Full text] [doi: 10.4414/smw.2011.13233] [Medline: 21769754]
4. Sugimori Y, Kusunoki K, Cho F, Uchikawa S. Toyota production system and Kanban system materialization of just-in-time and respect-for-human system. Intl J Production Res 1977 Jan;15(6):553-564. [doi: 10.1080/00207547708943149]
5. DOH. Framework for technology enhanced learning. 2012. URL: https://www.gov.uk/government/publications/a-framework-for-technology-enhanced-learning [accessed 2013-09-14] [WebCite Cache ID 6JcKTfn6D]
6. Markoff J. Entrepreneurs see a Web guided by common sense. New York Times. 2006. URL: http://www.nytimes.com/2006/11/12/business/12web.html?ex=1320987600&en=254d697964cedc62&ei=5088 [accessed 2013-09-04] [WebCite Cache ID 6JcKc2LOk]
7. DiRenzo MS, Linnehan F, Shao P, Rosenberg WL. A moderated mediation model of e-mentoring. J Vocat Behav 2010 Apr;76(2):292-305. [doi: 10.1016/j.jvb.2009.10.003]

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8. Thomas RG, John NW, Delieu JM. Augmented reality for anatomical education. J Vis Commun Med 2010 Mar;33(1):6-15. [doi: 10.3109/17453050903557359] [Medline: 20297908]
9. Linden. Second Life. 2011. URL: http://secondlife.com/ [accessed 2013-09-14] [WebCite Cache ID 6JcKlZSEi]
10. Forterra. Olive. 2011. URL: http://www.saic.com/products/simulation/olive/ [accessed 2013-09-14] [WebCite Cache ID 6JcKtIl55]
11. Boulos MN, Hetherington L, Wheeler S. Second Life: an overview of the potential of 3-D virtual worlds in medical and health education. Health Info Libr J 2007 Dec;24(4):233-245. [doi: 10.1111/j.1471-1842.2007.00733.x] [Medline: 18005298]
12. Heinrichs WL, Youngblood P, Harter P, Kusumoto L, Dev P. Training healthcare personnel for mass-casualty incidents in a virtual emergency department: VED II. Prehosp Disaster Med 2010;25(5):424-432. [Medline: 21053190]
13. Meskó B. How and why to use Second Life for education? ScienceRoll. 2007. URL: http://scienceroll.com/2007/09/19/how-and-why-to-use-second-life-for-education/ [accessed 2013-09-14] [WebCite Cache ID 6JcL9ZUxj]
14. Dev P, Heinrichs WL, Youngblood P. CliniSpace: a multiperson 3D online immersive training environment accessible through a browser. Stud Health Technol Inform 2011;163:173-179. [Medline: 21335784]
15. Toro-Troconis M, Kamat A, Partridge MR. Design and development of a component-based system for virtual patients in the virtual world of Second Life®. J Emerg Technol Web Intell 2011 Nov 01;3(4):308-316. [doi: 10.4304/jetwi.3.4.308-316]
16. Goodchild L. Researchers pilot virtual clinic to help train doctors. London. 2009. URL: http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_6-3-2009-15-46-3 [accessed 2013-09-14] [WebCite Cache ID 6JcLRyszb]
17. Oishi L. Surfing Second Life: what does Second Life have to do with real world learning? (virtual world). Tech Learn 2007;27(11):54 [FREE Full text]
18. Tan SS, Sarker SK. Simulation in surgery: a review. Scott Med J 2011 May;56(2):104-109. [doi: 10.1258/smj.2011.011098] [Medline: 21670138]
19. Crochet P, Aggarwal R, Dubb SS, Ziprin P, Rajaretnam N, Grantcharov T, et al. Deliberate practice on a virtual reality laparoscopic simulator enhances the quality of surgical technical skills. Ann Surg 2011 Jun;253(6):1216-1222. [doi: 10.1097/SLA.0b013e3182197016] [Medline: 21516035]
20. Mohtashami F, von Dadelszen P, Allaire C. A surgical virtual reality simulator distinguishes between expert gynecologic laparoscopic surgeons and perinatologists. JSLS 2011;15(3):365-372 [FREE Full text] [doi: 10.4293/108680811X13125733356477] [Medline: 21985726]
21. Voelker W, Maier S, Lengenfelder B, Schöbel W, Petersen J, Bonz A, et al. Improved quality of coronary diagnostics and interventions by virtual reality simulation. Herz 2011 Aug;36(5):430-435. [doi: 10.1007/s00059-011-3488-6] [Medline: 21748387]
22. Boyle E, O'Keeffe DA, Naughton PA, Hill AD, McDonnell CO, Moneley D. The importance of expert feedback during endovascular simulator training. J Vasc Surg 2011 Jul;54(1):240-248.e1. [doi: 10.1016/j.jvs.2011.01.058] [Medline: 21636241]
23. Patel V, Aggarwal R, Osinibi E, Taylor D, Arora S, Darzi A. Operating room introduction for the novice. Am J Surg 2012 Feb;203(2):266-275. [doi: 10.1016/j.amjsurg.2011.03.003] [Medline: 21703594]
24. Schmidt B, Stewart S. Implementing the virtual reality learning environment: Second Life. Nurse Educ 2009;34(4):152-155. [doi: 10.1097/NNE.0b013e3181aabbe8] [Medline: 19574850]
25. Weiner E, McNew R, Trangenstein P, Gordon J. Using the virtual reality world of Second Life to teach nursing faculty simulation management. Stud Health Technol Inform 2010;160(Pt 1):615-619. [Medline: 20841760]
26. Mitchell S, Heyden R, Heyden N, Schroy P, Andrew S, Sadikova E, et al. A pilot study of motivational interviewing training in a virtual world. J Med Internet Res 2011;13(3):e77 [FREE Full text] [doi: 10.2196/jmir.1825] [Medline: 21946183]
27. Hall V, Conboy-Hill S, Taylor D. Using virtual reality to provide health care information to people with intellectual disabilities: acceptability, usability, and potential utility. J Med Internet Res 2011;13(4):e91 [FREE Full text] [doi: 10.2196/jmir.1917] [Medline: 22082765]
28. Jaffer U, Standfield NJ. Mentor [Second Life]. 2011. URL: http://slurl.com/secondlife/Bangor%20University/172/40/27 [accessed 2013-09-14] [WebCite Cache ID 6JcMObgzS]
29. Hill J, Rolfe IE, Pearson SA, Heathcote A. Do junior doctors feel they are prepared for hospital practice? A study of graduates from traditional and non-traditional medical schools. Med Educ 1998 Jan;32(1):19-24. [Medline: 9624395]
30. LeRoy Heinrichs W, Youngblood P, Harter PM, Dev P. Simulation for team training and assessment: case studies of online training with virtual worlds. World J Surg 2008 Feb;32(2):161-170. [doi: 10.1007/s00268-007-9354-2] [Medline: 18188640]
31. Hansen MM, Murray PJ, Erdley WS. The potential of 3-D virtual worlds in professional nursing education. Stud Health Technol Inform 2009;146:582-586. [Medline: 19592909]
32. Panopoulos AP, Sarri K. E-mentoring: the adoption process and innovation challenge. Intl J Inform Manage 2013 Feb;33(1):217-226. [doi: 10.1016/j.ijinfomgt.2012.10.003]
33. Blumler JG. The role of theory in uses and gratifications studies. Commun Res 1979 Jan 01;6(1):9-36. [doi: 10.1177/009365027900600102]
34. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quart 1989 Sep;13(3):319-340. [doi: 10.2307/249008]

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Abbreviations

CT1: core surgical training 1
CT2: core surgical training 2
FY1: foundation year 1
FY2: foundation year 2
SL: Second Life
3D: three-dimensional

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Original Paper

Ecological Validity of Virtual Reality Daily Living Activities Screening for Early Dementia: Longitudinal Study

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Abstract

Background: Dementia is a multifaceted disorder that impairs cognitive functions, such as memory, language, and executive functions necessary to plan, organize, and prioritize tasks required for goal-directed behaviors. In most cases, individuals with dementia experience difficulties interacting with physical and social environments. The purpose of this study was to establish ecological validity and initial construct validity of a fire evacuation Virtual Reality Day-Out Task (VR-DOT) environment based on performance profiles as a screening tool for early dementia.

Objective: The objectives were (1) to examine the relationships among the performances of 3 groups of participants in the VR-DOT and traditional neuropsychological tests employed to assess executive functions, and (2) to compare the performance of participants with mild Alzheimer's-type dementia (AD) to those with amnestic single-domain mild cognitive impairment (MCI) and healthy controls in the VR-DOT and traditional neuropsychological tests used to assess executive functions. We hypothesized that the 2 cognitively impaired groups would have distinct performance profiles and show significantly impaired independent functioning in ADL compared to the healthy controls.

Methods: The study population included 3 groups: 72 healthy control elderly participants, 65 amnestic MCI participants, and 68 mild AD participants. A natural user interface framework based on a fire evacuation VR-DOT environment was used for assessing physical and cognitive abilities of seniors over 3 years. VR-DOT focuses on the subtle errors and patterns in performing everyday activities and has the advantage of not depending on a subjective rating of an individual person. We further assessed functional capacity by both neuropsychological tests (including measures of attention, memory, working memory, executive functions, language, and depression). We also evaluated performance in finger tapping, grip strength, stride length, gait speed, and chair stands separately and while performing VR-DOTs in order to correlate performance in these measures with VR-DOTs because performance while navigating a virtual environment is a valid and reliable indicator of cognitive decline in elderly persons.

Results: The mild AD group was more impaired than the amnestic MCI group, and both were more impaired than healthy controls. The novel VR-DOT functional index correlated strongly with standard cognitive and functional measurements, such as mini-mental state examination (MMSE; rho=0.26, *P*=.01) and Bristol Activities of Daily Living (ADL) scale scores (rho=0.32, *P*=.001).

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Conclusions: Functional impairment is a defining characteristic of predementia and is partly dependent on the degree of cognitive impairment. The novel virtual reality measures of functional ability seem more sensitive to functional impairment than qualitative measures in predementia, thus accurately differentiating from healthy controls. We conclude that VR-DOT is an effective tool for discriminating predementia and mild AD from controls by detecting differences in terms of errors, omissions, and perseverations while measuring ADL functional ability.

(JMIR Serious Games 2013;1(1):e1) doi:10.2196/games.2778

Introduction

A decade ago, Chaytor and Schmitter-Edgecombe [1] reviewed the ecological validity of neuropsychological tests by evaluating their efficacy in measuring everyday cognitive skills. They identified 6 studies that explored the issue of ecological validity of executive functioning tests. The studies differed in terms of the specific tests used, although both traditional (veridicality) and verisimilitude tests were employed. Veridicality refers to the extent to which results of an assessment instrument are related to scores on other tests that predict the performance of real-world tasks [2]. By contrast, verisimilitude refers to the similarity between the task demands of the test and the demands imposed in the everyday environment.

Their findings indicated that executive tests were not significantly correlated with self-reported measures, but all studies reviewed revealed significant associations between executive tests (traditional and verisimilitude) and everyday abilities as measured by clinician ratings and informants' (eg, relatives') questionnaires. To date, commentaries on ecological validity have primarily emphasized the increased consideration of this concept in assessments of neurologically impaired individuals, particularly in rehabilitative and forensic contexts. However, there are instances in which patients perform normally on traditional executive tests, yet clearly have executive impairments in their daily lives [3].

Virtual environments (VEs) have numerous features that make them attractive for assessment and rehabilitation purposes. In contrast to traditional executive test measures, VEs actively engage participants by allowing them to be involved in a task while at the same time being less focused on the fact that they are being tested [4,5]. More recently, researchers have used virtual reality (VR) systems for detailed response measurement and analysis to examine specific behaviors characteristic of patients with executive dysfunction or people with intellectual disabilities [6]. Klinger and colleagues [7] examined planning deficits in patients with Parkinson's disease compared to age-matched controls in a virtual supermarket. The researchers described the patients' paths through the supermarket as characterized by numerous stops, turns, and hesitancies as compared to the paths of controls. Zhang and colleagues [8] used a virtual kitchen to assess selected cognitive functions of traumatic brain injury patients compared to normal volunteers.

Task transparency and relevant functional tasks, such as finding one's way through a VE or remembering groceries for preparing a breakfast in a virtual kitchen, are examples in which ecological validity can be described as enhanced when compared to abstract traditional assessments of cognitive functions. A variety of VEs have already been developed to enhance functional assessment and rehabilitation, including virtual cities [9,10], school classrooms [11], and supermarkets [9,12]. As outlined previously, ecological validity can be seen as a key component for assessing cognitive skills that are relevant for functional tasks in real-world contexts [13]. The results of such studies suggest that the use of VEs is valuable in enhancing our ability to assess the functional behaviors of individuals with executive dysfunction in activities of daily living.

Activities of daily living (ADL) can be classified into basic activities of daily living (BADL) and instrumental activities of daily living (IADL) [14]. BADL is composed of more basic self-care behaviors, such as ambulating, dressing, grooming, bathing, feeding, and toileting. By contrast, IADL facilitates independent living through behaviors such as transportation, telephone use, meal preparation, medication management, financial management, housekeeping, laundry, and shopping. IADL questionnaires play a vital role in assessing functional abilities and evaluating the impact of cognitive impairment on everyday activities in older adults [15].

IADL independence is one of the defining features that characterize normal aging from mild cognitive impairment (MCI) and dementia. As part of the diagnostic criteria for MCI, an individual must be classified as independent for BADL, but can have minimal disturbance in IADL [16,17]. Since the early descriptions of MCI [16], there has been increasing interest in its clinical characterization and prognosis [18,19]. In previous reports [20], people with MCI exhibited poorer cognitive functioning than healthy controls, but were not as impaired as patients with dementia were.

Prognostic studies have stressed the necessity of this nosological entity as a risk, or prodromal state for dementia, because of the high rate of conversion of MCI to dementia (10%-15% of patients who meet the criteria of amnestic MCI develop Alzheimer-type dementia per year, up to 80% at 5-year follow-up) [21,22,18]. In Europe, approximately 17% of the senior population who have not been diagnosed with dementia meet the current criteria for MCI [23] and MCI prevalence increases with age [24].

Characterizing impairment using the IADL questionnaire has been criticized for several reasons. First, no objective standard exists as to the practical or theoretical definition of minimal functional impairment in predementia [16,17]. For example, does functional disturbance entail perceptible impairment on a few IADL tasks, such as shopping and meal preparation? Or is it better understood as some problems across many commonly assessed IADL tasks? Clinical judgment is called for by the expert panel that created these standards [25,26], but the general clinician or researcher is without much guidance regarding how to assess IADL impairment in predementia patients. Several

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options exist, including performance-based tasks and questionnaires or interviews (with and without informant reports). However, different methods of assessing functional abilities require different estimates of IADL independence [27]; each method has advantages and disadvantages.

Recently, it became clear that IADL, versus BADL, is a better diagnostic instrument for predementia [28-31]. Although these studies were carried out in different countries and used different instruments to assess impairments in ADL, they all indicate that people who meet the criteria described for predementia show some functional impairment in activities of daily living. In the clinical setting, rate of change in complex ADL performance may be more useful than a cross-sectional measurement, which could misclassify individuals into a nonimpaired category in activities of daily living [32]. Furthermore, the rate of change is a parameter that could be manipulated by designing naturalistic VEs or serious games that can train the higher cognitive functions.

We designed a fire evacuation Virtual Reality Day-Out Task (VR-DOT) environment to (1) determine what kind of real-time cognitive and psychomotor performance and errors are associated with functional impairment in activities of daily living, (2) identify the patterns and cutoff values of the these cognitive and psychomotor profiles as independent predictors of functional impairment in healthy elderly participants, single-domain amnestic MCI patients, and patients with mild Alzheimer-type dementia (AD), and (3) controlling for baseline performance, objectively measure performance change over 2 to 3 years.

We hypothesized that with VR-DOT (1) dementia and MCI patients will show significantly impaired independent functioning in ADL and distinct performance profiles, (2) among patients with dementia or MCI, such impairment will be associated with the degree of cognitive impairment and cognitive neurophysiological measures, whereas impaired functioning will be only associated with sociodemographic and anxiety/depression symptoms in healthy controls because subclinical levels of cognitive impairment and depression have been associated with IADL impairment in mentally healthy participants [33], and (3) in mild AD and MCI patients, the rate of change in individual performance in VR-DOT measures could predict the cognitive decline over 2 to 3 years.

The main objective in developing the VR-DOT was to improve the ecological validity of executive function measures by using a verisimilitude approach. We also proposed a framework to objectively assess the functional impairment of elderly people through an ecological and clinical longitudinal experiment using VR-DOT. Our motivation was to correlate this new instrument (VR-DOT) with normal cognitive neuropsychological measures and recent psychomotor discoveries regarding psychomotor velocity change and cognitive decline to see if the VR-DOT offers better sensitivity and specificity in assessing and predicting cognitive decline using only a virtual environment.

Methods

Virtual Reality Test Setup

Overview

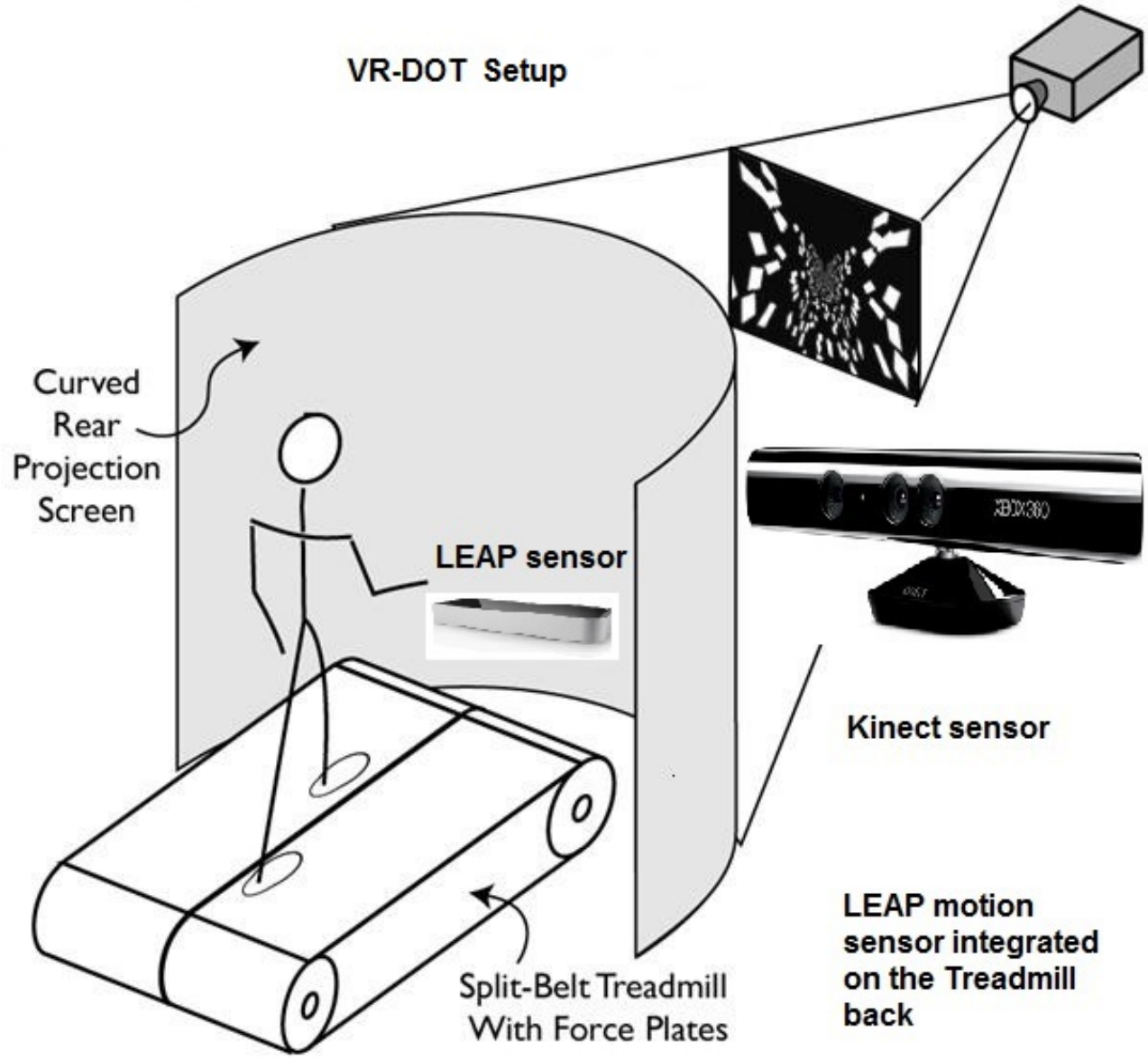
The VR hardware consisted of a Pentium-based computer with 4 MB RAM, Intel Quad Core processor, and NVIDIA graphic cards with 512 MB memory. Other sensors used were a LEAP motion sensor (Leap Motion Inc, San Francisco, CA, USA) and a Kinect camera (Microsoft Corp, Seattle, WA, USA). The LEAP motion sensor is still not commercially available at the time of this writing, but we were selected by their development team to use the hardware for our experiments (Figure 1).

Software Components

Modeling was done using Maya software (Autodesk Inc, San Rafael, CA, USA) to create models and scenes. Then, the scenes were exported to Virtools, a 3D authoring tool (Dassault Systèmes, Inc, Vélizy-Villacoublay Cedex, France) that handled all programming including interactivity, setting, and configuration. Microsoft Kinect software development kit (SDK) (Microsoft Corp, Seattle, WA, USA) was used to analyze gestures and movements and a user interface (UI) system was developed using Microsoft Kinect SDK and precommercial Alterniity algorithms developed by Ioannis et al [34].

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Figure 1. Virtual reality day-out task (VR-DOT) participant setup.



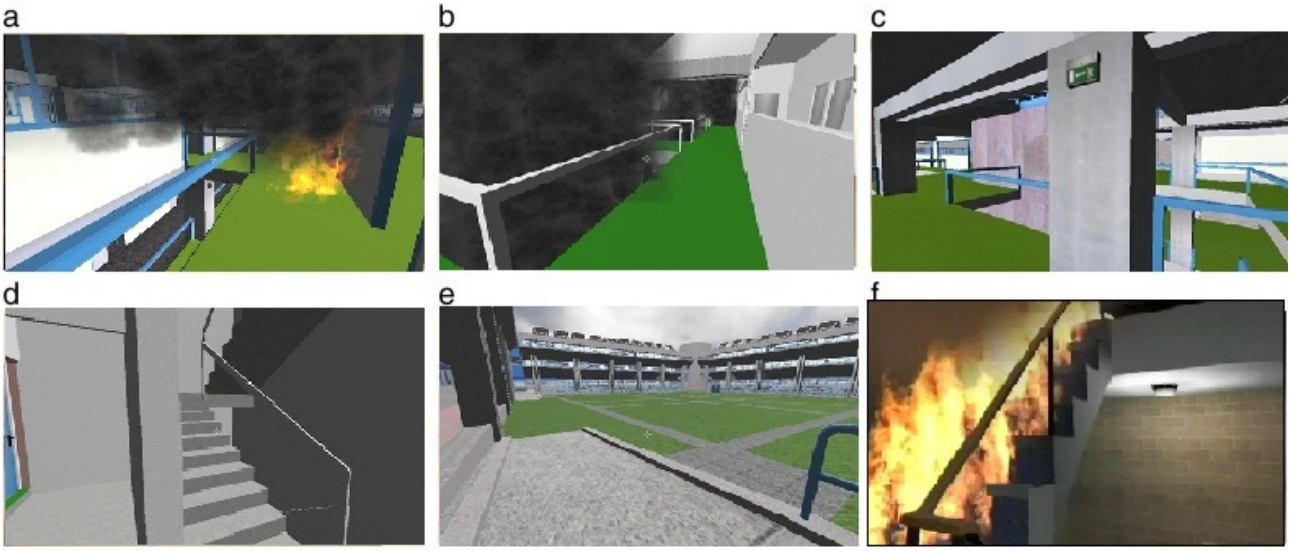
The Naturalistic Setting of Executive Function in Virtual Reality Activities of Daily Living

Virtual reality activities of daily living (VR-ADL) consists of 2 modules: the VR-DOT and VR basic instrumental activities of daily living (VR-IADLs). The VR-DOT is a complex task breakdown and then a rehearsal exercise of a fire evacuation drill consisting of 6 different scenarios of increasing difficulty. We chose to examine the VR-DOT virtual fire evacuation drill in this study (Figure 2), based on the literature indicating that activities of daily living requiring complex reasoning are sensitive to cognitive and functional impairment [35]. User tracking was performed by a flexible action and articulated skeleton toolkit (FAAST; University of Southern California, CA, USA), a middleware to facilitate integration of full-body control with games and VR applications, using either OpenNI or the Microsoft Kinect for Windows skeleton tracking software. FAAST includes a custom virtual reality peripheral network (VRPN) server to stream up to 4 user skeletons over a network, allowing VR applications to read the skeletal joints as trackers using any VRPN client. Additionally, the toolkit can also emulate keyboard input triggered by body posture and specific gestures. This allows the user to add custom body-based control mechanisms to existing off-the-shelf games that do not provide official support for depth sensors.

More specifically, the VR-DOT module is a naturalistic task that requires multitasking in a fire evacuation drill setting with 6 different simulated fire situations (from easy to more difficult) taking place at a virtual apartment block with 3 levels and 5 apartments per level. It is used to examine prospective memory as well as reasoning in a complex emergency routine in which older adults prioritize, organize, initiate, and complete a number of subroutines to evacuate safely from an apartment level (second floor) to the ground area (eg, determine and gather information on the size of the fire, avoid smoke). Previous research shows that motion tracking while navigating a virtual environment is a valid and reliable indicator of cognitive decline in elderly persons. (ie, [36]).

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Figure 2. Sample sequential virtual reality day-out task (VR-DOT) screenshots, showing different tasks and viewpoints.



Functional and Psychomotor Rate of Change

A measurement of the rate of change of functional impairment was computed from all information collected from the LEAP motion and the Microsoft Kinect camera sensor inside the VR-DOT. Simple performance-based functional impairment measures have been used previously, but not with data collected from motion sensors [37]. At baseline, a simple quantitative ratio of efficacy was computed by dividing the total time (in sec) spent by the participant performing the listed activities by the total time spent in VR-DOT (efficacy ratio). Then, 4 activity parameters with a high likelihood of corresponding to functional decline were collected: (1) omission of 1 of the activities (k_1), (2) repetition of the same activity (k_2), (3) incorrect order in performing the activities (k_3), and (4) number of attempts before completing a given activity (k_4). The first quantitative ratio of efficacy was then adjusted by these parameters. This led to a functional impairment score according to the formula presented in Multimedia Appendix 1.

To determine values of the model parameter set (k_1, k_2, k_3, k_4), we ran a pilot with healthy participants (n=25; mean age 73.7 years, SD 4.0), amnestic single-domain MCI patients (n=26; mean age 74.2 years, SD 2.0), and patients with mild AD (n=24; mean age 76.7 years, SD 3.0). Second, multiple-model parameter sets (k_1, k_2, k_3, k_4) to produce a good fit were selected if their associated scores were both strongly and positively correlated with the mini-mental state examination (MMSE) scores, as well as being strongly and negatively correlated with IADL scores using a nonparametric Spearman correlation coefficient as the criterion distance of good fit. For our analyses, the final functional impairment score (k_1, k_2, k_3, k_4) was calibrated using the combination of the mean of the parameters, which was selected as the model parameter set during the second step of the fitting procedure.

Procedure

Participants

A total of 405 elderly people were screened during 2010 in 2 Alzheimer Hellas, Non-Government Organization (NGO) day clinics of the Papanikolaou University Hospital in Thessaloniki, Greece. Ethics approval was obtained from the Papanikolaou University Hospital Ethics Committee. Inclusion criteria were age older than 60 years, meeting the diagnostic criteria for MCI as defined in Petersen et al [18], living in the community, and providing informed consent approved by the Ethics Committee. Exclusion criteria were living in an assisted-living residence, cognitive functioning suggesting a possible diagnosis of dementia (see subsequent description), previous diagnosis of dementia, other psychiatric disorder according to the *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition, Text Revision; *DSM-IV-TR*) at the time of recruitment, presenting a moderate or higher degree of fear or dislike of computers (technophobia), presenting a moderate or higher degree of disability because of other conditions than MCI, and severe language impairments that would compromise active participation.

The baseline psychomotor evaluation inside VR-DOT consisted of a number of simple and complex measures addressing the participant's ability to understand and perform with accuracy specific physical performance tasks. These tasks/metrics were:

Grip Strength

Forearm muscle strength was measured in kilograms by a hand-held Jamar A dynamometer. For this analysis, we used the best of 3 attempts in the dominant hand.

Timed Walk on the Treadmill

The time (to 0.1 s) required for a participant to walk a 4.6-m course at his or her usual pace after starting from a standstill was recorded by stopwatch. We converted the results to meters per second.

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Number of Steps to Walk Course on the Treadmill

A technician recorded the number of steps required to walk the 4.6-m course. Hereafter, we refer to stride length, which is derived by dividing the distance walked by the number of steps.

Finger-Tapping Test

Using their dominant hand, participants tapped in midair, just above the LEAP motion sensor, with the index finger as fast as they could for 15 seconds.

After applying the inclusion/exclusion criteria, 232 participants were included in this study. The participants were measured each year of the 3-year study period. Dropouts after baseline were 27 (11.6%); hence, 205 participants completed all measurements and their data are included in this study (N=205; male=88, female=117; mean age 72.73 years, SD 6.89; mean education 12.53 years, SD 3.20; mean baseline MMSE 24.75, SD 2.18).

Neuropsychological Assessment

Cognitive assessment was performed by means of a neuropsychological test battery designed to comprehensively evaluate attention, working memory, memory, executive functioning, and language. In addition to the cognitive assessment, all groups were also assessed for depression with the geriatric depression scale (GDS) [38]. We also chose the Digit Symbol (DSym), Functional Activities Questionnaire (FAQ), Neuropsychiatric Inventory brief questionnaire form, Apathy item (NPI-Q Apathy), Neuropsychiatric Inventory brief questionnaire form, Depression item (NPI-Q Depression), Rey Auditory Verbal Learning Test T (RAVL), Trailmaking Test A (TMT-A), Trailmaking Test B (TMT-B), Trailmaking Test B minus Trailmaking Test A (TMT-B-A), the Bristol ADL scale, and the short form of the Blessed ADL scale for this study because they were evaluated and validated for the Greek population [39]. The original Bristol and short-form Blessed scales consist of 20 and 11 items, respectively.

Statistical Analysis

Performance results from the VR-DOT, gait velocity assessment, and neuropsychological tests were analyzed using multivariate analyses of variance (MANOVA) in mixed designs with group as the between-subject factor using linear mixed-effects models with random intercept and slope to estimate the annual rate of change between study years 1 and 3 for each performance measure of each participant [40,41]. Before this approach, we plotted numerous individual trajectories for the gait velocity performance variables by using robust splines to smooth the curves. The consistent linearity of the trajectory patterns justified the use of linear models. Gait speed and stride length were adjusted to a 50-cm knee-heel length and this adjustment was included in the models when it reached 10% significance. We also used multinomial Poisson log-linear models to estimate the relative risk (RR) of cognitive decline relative to efficacy, gait velocity, and neuropsychological assessment at year 2 and year 3 (2010-2013) for VR-DOT and receiver-operating curve (ROC) analysis was conducted on VR-DOT, MMSE, the RAVLT, and the Bristol and Blessed ADL scale scores.

Significant effects were further tested with post hoc tests that were corrected for multiple comparisons using Tukey's Honestly Significant Difference (HSD) [42]. We used similar statistical models to estimate the RR of having significant VR-DOT difficulty or inability (relative to no or mild difficulty) and the RR of cognitive decline (relative to no or mild difficulty) at year 3 for upper extremity function. For a given performance measure, the first year 1 value and the third year 1-3 slope of change were treated as separate predictor variables. For each outcome, a separate regression model was run for each predictor performance variable, adjusting for age, gender, and the VR-DOT task of more difficulty with, or disability in, the outcome measure between years 1 and 3. Next, we simultaneously entered all predictor performance variables into a second set of models, adjusting for the same covariates. The component variables from each model were entered, in turn, into a stepwise backward regression for the respective outcomes, with a P value to enter the model set at <.10. This procedure yielded a set of simpler, more parsimonious final models. All statistical analyses were run using SPSS 19.0 statistical software (IBM Corp, Armonk, NY, USA).

Results

Demographics and baseline scores for all groups are shown in Table 1.

After corrected with age, gender, and education status, our results showed that the VR-DOT functional index was correlated strongly with standard cognitive and functional measurements, such as MMSE (rho=0.26, P=.01) and Bristol ADL scores (rho=0.32, P=.001), thus accurately differentiating from healthy control participants (Table 2).

In the prediction models for individual performance measures (not shown), the VR-DOT and upper extremity function psychomotor performance (finger tapping, etc) at year 3 for the MCI and mild AD group, as well as the slopes of change, had a significance of P<.10. Compared with the control, weaker results of the MCI and mild AD independently predicted cognitive decline at year 3 in all 3 domains (VR-DOT, neuropsychological, and gait velocity assessment). The change slope for upper extremity function inside the VR-DOT was also associated with the outcome.

For functional independence, the healthy group showed better functional adjustment than the MCI and mild AD group according to VR-DOT total monitoring data. When the amnestic MCI group was examined using the VR-DOT total score, cognitive domain and gait velocity assessment showed a similarly impaired profile as cognitive functioning, after controlling for age, education, and GDS score. The mild AD patients showed a higher degree of functional impairment than both healthy controls and amnestic MCI patients in life activities, and participation subscales, respectively, and in the VR-DOT mobility domain. The total VR-DOT functional ability measures showed a consistent functional impairment of mild AD and amnestic MCI in comparison with healthy participants.

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Table 1. Participant demographics and scores on cognitive tests for all participants, healthy controls, patients with amnestic-type mild cognitive impairment (aMCI), and patients with mild Alzheimer-type dementia (AD).

Group	All participants N=205	Controls n=72	aMCI n=65	Mild AD n=68
Age, mean (SD)	72.73 (6.8)	72.63 (5.06)	72.78 (6.21)	72.58 (6.21)
Sex, n (%)				
Male	88 (43%)	25 (38%)	30 (43%)	33 (46%)
Female	117 (57%)	37 (62%)	40 (57%)	40 (54%)
Education, mean (SD)	15.6 (3.0)	16.1 (2.9)	15.7 (3.0)	14.6 (3.2)
Test, [a] mean (SD)				
MMSE	24.75 (2.18)	29.1 (1.0)	26.1 (1.8)	23.4 (2.0)
RAVLT delayed recall	3.7 (4.0)	7.4 (3.7)	2.9 (3.3)	0.7 (1.6)
GDS	1.4 (1.4)	0.8 (1.1)	1.6 (1.4)	1.6 (1.4)
NPI-Q depression	0.2 (0.5)	0.1 (0.3)	0.2 (0.5)	0.4 (0.6)
NPI-Q apathy	0.2 (0.6)	0.01 (0.1)	0.2 (0.5)	0.5 (0.8)
FAQ	4.8 (6.4)	0.1 (0.6)	3.8 (4.4)	12.7 (6.7)
TMT-A	46.6 (25.5)	36.3 (13.0)	44.2 (21.7)	64.8 (34.5)
TMT-B	134.5 (80.2)	89.3 (44.3)	130.8 (73.2)	200.5 (86.6)
TMT-B–A	88.0 (66.9)	53.0 (38.8)	86.6 (63.1)	135.8 (74.3)
Bristol ADL scores	6.88 (0.56)	4.46 (0.5)	5.59 (0.9)	10.59 (0.9)
Blessed ADL impairment score	2.87 (0.26)	1.85 (0.27)	2.38 (0.56)	4.38 (0.56)
Geriatric depression scale	5.19 (5.0)	4.59 (4.1)	5.49 (5.76)	5.29 (4.45)
Digit Symbol	37.4 (12.9)	45.8 (10.2)	37.0 (11.1)	27.6 (12.5)
Gait speed (m/s), mean (SD)				
Combined	0.91 (0.22)	0.96 (0.23)	0.91 (0.24)	0.86 (0.20)
Women	0.85 (0.14)	0.94 (0.24)	0.84 (0.04)	0.77 (0.14)
Men	0.98 (0.13)	1.00 (0.21)	1.01 (0.03)	0.95 (0.04)
Tapping speed dominant (taps/second), mean (SD)				
Combined	3.79 (0.8)	3.87 (0.8)	3.77 (0.81)	3.74 (0.8)
Women	3.48 (0.78)	3.53 (0.71)	3.49 (0.84)	3.43 (0.77)
Men	4.23 (0.75)	4.29 (0.77)	4.21 (0.73)	4.19 (0.75)
Tapping speed non-dominant (taps/second), mean (SD)				
Combined	3.60 (0.67)	3.63 (0.64)	3.61 (0.71)	3.58 (0.7)
Women	3.73 (0.59)	3.41 (0.53)	3.38 (0.64)	3.33 (0.61)
Men	3.92 (0.63)	3.91 (0.65)	3.96 (0.63)	3.90 (0.62)

[a]MMSE: mini-mental state examination, RAVLT: Rey Auditory Verbal Learning Test, GDS: Geriatric Depression Scale, NPI-Q Depression: Neuropsychiatric Inventory brief questionnaire form, Depression item, NPI-Q Apathy: Neuropsychiatric Inventory brief questionnaire form, Apathy item, FAQ: Functional Activities Questionnaire, TMT-A: Trailmaking Test), TMT-B: Trailmaking Test B, TMT-B–A: Trailmaking Test B minus Trailmaking Test A, ADL: Activities of Daily Living.

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Table 2. The correlation matrix between Virtual Reality Day-Out Task (VR-DOT) functional index, mini-mental state examination (MMSE), and Bristol Activities of Daily Living (ADL) when controlling for age, gender, and education status.

Test	VR-DOT		MMSE		Bristol ADL
	rho	*P* value	rho	*P* value	rho
VR-DOT	1				
MMSE	0.26	.01	1		
Bristol ADL	0.32	.01	0.43	.01	1

Predictors of Functional Status (Regression Analyses)

When the entire sample was analyzed together, attention, psychomotor, and memory summary scores explained a total variance of 8.2% and 0.8% of the VR-DOT. When depression and age were entered in both former models, the VR-DOT score was predicted by depression symptoms as measured by the GDS (19.2%) only in the healthy group. By contrast, VR-DOT total score was only predicted by psychomotor and executive functions (8.1%) among mild AD and amnestic MCI patients. For the amnestic MCI group, VR-DOT was predicted by executive functions and psychomotor profile only, with a total variance explained of 17.3% for amnestic MCI. VR-DOT score was predicted only by executive function and psychomotor profiles in amnestic MCI patients and by executive function, psychomotor profiles, and GDS scores in mild AD. When a ROC analysis was carried out on the Bristol and Blessed ADL scales, they explained 9.1% variance of VR-DOT total profiles.

ROC analysis was conducted on VR-DOT, MMSE, RAVLT, and Bristol and Blessed ADL scale scores obtained from the amnestic MCI and mild AD groups and the sensitivity, specificity, and cutoff values of both the scales were determined (Table 3). The optimal cutoff score of the Bristol scale was 20 in differentiating amnestic MCI from mild AD with a sensitivity of 100% and specificity of 74.2%, and area under the curve (AUC) of 0.883 (95% CI 0.781-0.975). The optimal cutoff score of the modified Blessed scale was 10.5 in differentiating amnestic MDI from mild AD with a sensitivity of 100%, specificity of 71%, and AUC 0.872 (95% CI 0.791-0.977). Post hoc analysis revealed that among the 3 groups, the mild AD group had the lowest scores in ADL, episodic memory, and VR-DOT (*P*<.001).

The AUC indicates that VR-DOT was the most powerful of all tests in discriminating normal controls from the MCI groups, reaching optimal results with a cutoff point of 20 (97% sensitivity, 100% specificity, 100% positive predictive values, and 96% negative predictive value). Figure 3 shows the ROC of the normal control and MCI groups for VR-DOT total score.

Exploratory Prediction of Conversion to Alzheimer Disease (VR-DOT Performance Rate of Change)

According to the results, the task that better differentiated among healthy controls, amnestic MCI, and mild AD participants at baseline, year 2, and year 3 follow-up, was the VR-DOT performance score (efficacy ratio). The VR-DOT and Bristol and Blessed ADL scale scores were included as predictor variables in a series of exploratory independent regression analyses. Figure 4 shows the individual predictive power of the 3 test variables of interest (VR-DOT, Bristol, and Blessed ADL scale scores), ranked in ascending order according to the magnitude of their odds ratios. The VR fire evacuation performance score rate of change (VR-DOT REff) emerged as the best predictor of conversion to AD in this sample (VR-DOT; *P*=.008; OR 2.8, 95% CI 1.3-6.0; Nagelkerke R^2=0.564), with the regression model correctly classifying 88% of participants. This was followed by Bristol ADL (*P*=.03; OR 1.9, 95% CI 1.1-3.5; Nagelkerke R^2= 0.563), and the Blessed ADL (*P*=.01; OR 1.4, 95% CI 1.1-1.9; Nagelkerke R^2=0.466).

The resulting regression model revealed that the VR-DOT performance score threshold variable was a significant predictor of conversion to AD in the regression equation (beta=–1.092, *P*=.01) with OR 3.0 (95% CI 1.3-7.0). Using a cutoff score of less than 20 on the VR-DOT subscale achieved a sensitivity of 100% and a specificity of 94%.

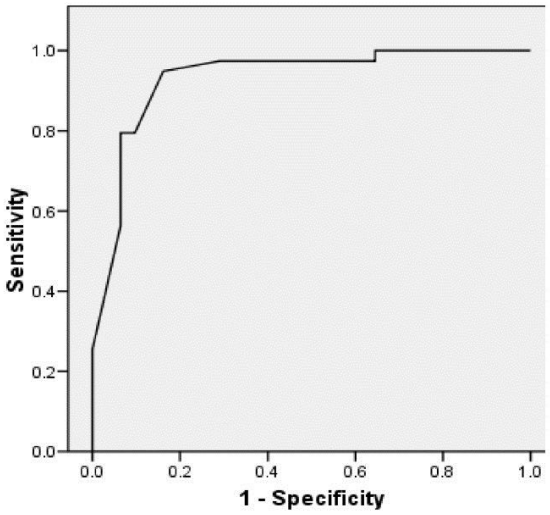
Table 3. Area under the curve (AUC) for standard neuropsychological test scores and Virtual Reality Day-Out Task (VR-DOT) for healthy controls versus patients with amnestic-type mild cognitive impairment (aMCI) and patients with aMCI versus patients with mild Alzheimer-type dementia (AD).

Test[a]	Healthy control vs aMCI		aMCI vs mild AD	
	AUC (95% CI)	*P* value	AUC (95% CI)	*P* value
MMSE	0.79 (0.68, 0.91)	<.001	0.99 (0.97, 1.00)	<.001
Bristol scores ADL	0.75 (0.62, 0.88)	<.001	0.88 (0.78, 0.97)	<.001
Blessed score ADL	0.77 (0.64, 0.89)	.002	0.87 (0.79, 0.98)	.02
RAVLT delayed recall	0.82 (0.77, 0.93)	.001	0.88 (0.79, 0.98)	<.001
DOT-VR	0.96 (0.88, 0.99)	<.001	0.95 (0.88, 1.00)	<.001

[a]MMSE: Mini-Mental State Examination, ADL: Activities of Daily Living, RAVLT: Rey Auditory Verbal Learning Test.

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Figure 3. Receiver-operating curve (ROC) for the Virtual Reality Day-Out Task (VR-DOT) total score when discriminating among nondemented (healthy controls), amnestic mild cognitive impairment (aMCI), and patients with mild Alzheimer-type dementia (mild AD).



Cutoff score = 20

Sensitivity = 100%

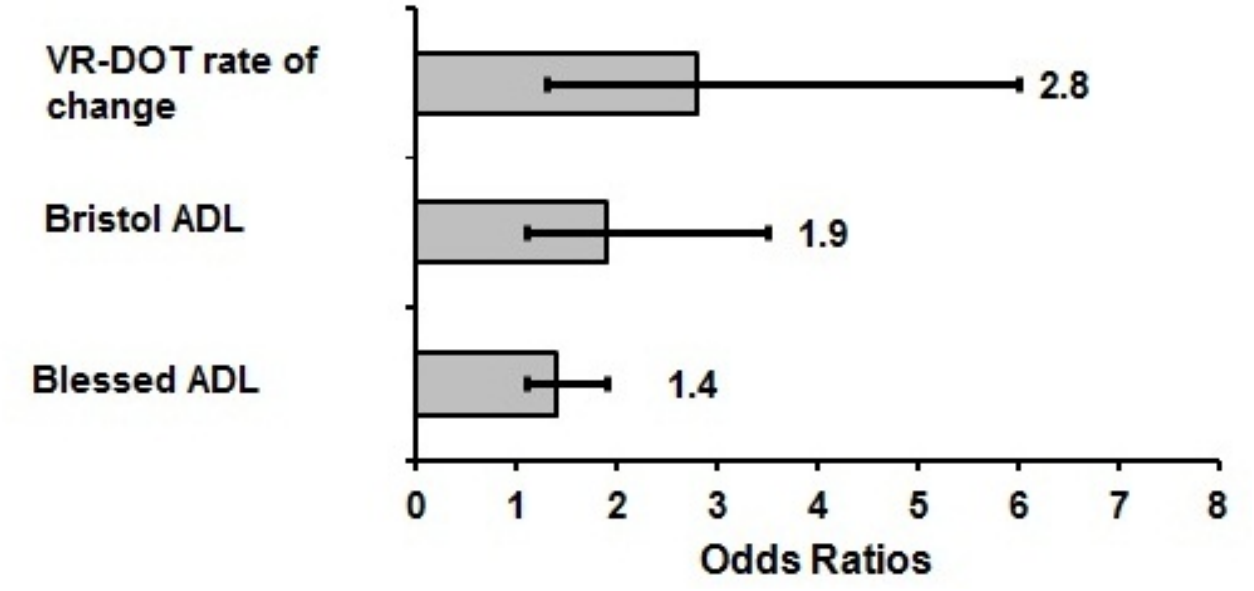
Specificity = 74.2%

Area under ROC (95% CI) = 0.933*

(0.871 – 0.995)

* P < .05

Figure 4. Odds ratios from exploratory individual regression analyses using VR-DOT, Bristol, and Blessed ADL scale scores rate of change as predictors for conversion from mild cognitive impairment to Alzheimer disease (bars represent 95% CI).



Discussion

There is still debate as to the utility of MCI as a diagnostic category. Many older people report subjective cognitive complaints in the absence of objective impairment [43] and not all such complaints are predictive of dementia [44]. MCI may be viewed as being on a continuum from normal aging to dementia and the present data show a large overlap between groups that coheres with this view [45]. In that context, only a few studies have systematically examined the rate of change in complex ADL performance as a predictor of cognitive decline.

Our results show that functional impairment is a defining feature of both amnestic MCI and mild AD, and that the impairment showed by amnestic MCI patients is partially dependent on the degree of their cognitive impairment. Furthermore, a virtual reality quantitative performance measure of functional ability (VR-DOT) showed adequate psychometric properties (ie, discriminant power) to contribute to a predementia diagnosis. In addition, functional measures based on quantitative rates of the number and quality of ADL performed seem to be more sensitive to identifying functional impairment in predementia than those based on a subjective judgment of disability.

As a result of this paradigm shift, and in light of previous and the present results, it would be very helpful for clinicians, caregivers, and health-system managers if MCI definitions included an objective measure of impairment of functional abilities as a clinical feature inherent to MCI. We found that VR-DOT has greater sensitivity and specificity, as well as having both positive and negative predictive values compared to other screening tests in discriminating amnestic MCI and

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mild AD from normal aging. In summary, these and previous results emphasize the presence of qualitative and quantitative functional impairments of both basic and complex ADL in predementia as a logical consequence of cognitive impairment. Although dementia is characterized by a more severe degree of disability than predementia, the World Health Organization (WHO) International Classification of Functioning, Disability and Health (ICF) conceptualization of disability would include predementia as a disabling condition, although to a lesser degree. The need for a better definition of disability as a diagnostic criterion (putatively by shifting from a categorical notion of able/disabled to a more spectrum/gradual approach) to discriminate predementia from dementia must not conceal the fact that dementia patients have their own health/functional assistance needs.

Moreover, given the moderately good psychometric properties demonstrated in our study of the VR-ADL in discriminating healthy from predementia and mild dementia patients, assessing real-time functional ability would improve the identification of predementia patients, and the use of objective, VR qualitative and/or quantitative impairment of functional abilities as a diagnostic criterion should be further explored. Goldberg et al [26] found that a sensitive performance-based measure they developed (the University of California, San Diego Performance-Based Skills Assessment; UPSA) had a remarkably good discriminant power to distinguish healthy participants from amnestic MCI participants (AUC 0.84), and to distinguish amnestic MCI patients from patients with AD (AUC 0.88). Hence, the inclusion of functional competence measures seems convenient for the screening and early identification of neurodegenerative processes characterized by cognitive impairment.

The rates of change in complex everyday activities, easily determined in longitudinal practice settings, provide important prognostic information for late-life disability and death that are independent of the predictive value of a performance measurement obtained at a single point in time, which could be inaccurate because of recent injury or illness. By predicting decline in ADL and IADL, upper extremity functionality, and more generalized daily activities, longitudinal views capture broader deteriorations in function within an individual, suggesting a shared causal pathway.

Our study has limitations. Although we used a population-based cohort, the exclusion from the analyses of participants with technophobia [46] may have introduced bias and reduced the generalizability of the results. Although we only observed linear patterns in the many performance trajectories that we plotted, some individual trajectories could have been nonlinear causing inaccurate estimates of annual performance change. Our statistical models contained a limited number of covariates. Although the addition of comorbid conditions to the models did not significantly alter the results, we may have omitted important confounders.

The present research described the ecological validity of verisimilitude and traditional activities of daily living measures and the characterization of various subcomponents of the executive function system. The unique contribution of this study was in the development and empirical study of a novel VR environment (VR-DOT) that was less structured and that more closely resembled actual everyday errands than existing questionnaires. This research demonstrated that tests of verisimilitude may be better predictors of real-world behaviors than many of the most commonly employed traditional executive function tests.

Our approach with VR-DOT is part of a general effort to manifest marked impairment in cognitive performance, particularly executive functions during everyday activities by means of VR (VR-ADL). Studies directly investigating ADL have found mild and tardive impairment in MCI, and a relation with certain executive functions, but the targeted ADL were very simple tasks, such as memorizing a telephone number or walking a few meters, and have always been strictly limited to the accuracy domain, excluding any performance or a rate-of-change factor. The purpose of VR-DOT was (1) to investigate performance, in an experimentally controlled manner, on a complex ADL (planning and evacuating a fire under time pressure) that is more indicative of the true quality of life of senior citizens, and (2) to scrutinize its cognitive structure as a diagnostic instrument, which can screen functional impairments at a very early phase of AD. With regard to real-life ADL, this investigation presents the advantage and innovation of a VR quantitative scoring grid of a very complex set of sequential activities under demanding time constraints.

This study found that VR-DOT is comparatively better in detecting amnestic MCI from normal aging individuals. From quantitative and qualitative data extracted from VR-DOT, a functional index was computed, validated, and compared with current clinical rating scales. Results of this pilot study are promising and must be substantiated with a larger sample and in another assessment setting to evaluate its reproducibility. Verisimilitude instruments, such as VR-DOT, can potentially play valuable roles in both executive function assessment and intervention and, consequently, may help place clinical neuropsychology on firmer scientific ground. Researchers and clinicians have the responsibility and opportunity to design, test, and implement effective therapeutic strategies to improve, or at least preserve, functional and cognitive functioning in predementia.

For these purpose, it is assumed that the visual quality and realism of the VEs are of central importance for patients to recognize and acknowledge the relevance of the task and context at hand. Essential characteristics of virtual scenarios and tasks (ie, transparency, believability, plausibility, and relevance) are summarized under the term “realism” to describe that the patient can recognize the employed tasks and scenarios and refer to them based on past experiences. VR-ADLs capture the patient’s interest and improve long-term motivation to use the virtual tasks at high frequencies. Transparency and realism in a broader sense can relate to plausibility and place illusions that are described by Slater [47]. Plausibility illusion refers to the fact that the user believes the virtual scenario is actually occurring. It is caused by events and the scenario relating directly to the user (eg, the virtual character talking to the user). Place illusion refers to the sensation that the user is actually situated in the displayed location and is described in relation to sensorimotor

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contingencies of the VR system (eg, user interaction, tracking, and multimodal user feedback). VR-ADL, task transparency, and relevant virtual scenarios are believed to contribute to the described illusions that virtual events and locations are actually relevant to the user and engaging for cognitive rehabilitation. For example, a cognitive task embedded in a user-relevant scenario directly relates to the therapy goal of the patient and represents a desired outcome of the patient's rehabilitation (eg, a virtual kitchen with cooking tasks relates to the scenario that the patient aims to engage in independently at home).

The VR system used here is portable and can be manipulated to simulate different environments and different navigation demands (cognitive, motor, visual), easily allowing the creation of an ecologically valid study and testing in a variety of clinical and research settings.

In conclusion, relative to age-matched controls, VR-ADL exercises outperform the clinical predictive validity of traditional assessments as an indicator of real-world difficulties in IADLs. This result is very promising, but we will need advanced imaging techniques, such as amyloid-positron emission testing or functional magnetic resonance imaging, to study this relationship and perform a longitudinal study that would correlate our results with neuroimaging data as well.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Efficacy ratio and functional impairment score formula.

[JPG File, 28KB - games_v15i8e156_app1.jpg]

References

1. Chaytor N, Schmitter-Edgecombe M. The ecological validity of neuropsychological tests: a review of the literature on everyday cognitive skills. Neuropsychol Rev 2003 Dec;13(4):181-197. [Medline: 15000225]
2. Franzen MD, Wilhelm KL. Conceptual foundations of ecological validity in neuropsychological assessment. In: Sbordone RJ, Long CJ, editors. Ecological Validity of Neuropsychological Testing. Boca Raton, FL: St Lucie Press; 1996.
3. Thompson CL, Henry JD, Withall A, Rendell PG, Brodaty H. A naturalistic study of prospective memory function in MCI and dementia. Br J Clin Psychol 2011 Nov;50(4):425-434. [doi: 10.1111/j.2044-8260.2010.02004.x] [Medline: 22003951]
4. Cesa GL, Manzoni GM, Bacchetta M, Castelnuovo G, Conti S, Gaggioli A, et al. Virtual Reality for Enhancing the Cognitive Behavioral Treatment of Obesity With Binge Eating Disorder: Randomized Controlled Study With One-Year Follow-up. J Med Internet Res 2013;15(6):e113 [FREE Full text] [doi: 10.2196/jmir.2441] [Medline: 23759286]
5. Rizzo AA, Buckwalter JG. Virtual reality and cognitive assessment and rehabilitation: the state of the art. Stud Health Technol Inform 1997;44:123-145. [Medline: 10175336]
6. Hall V, Conboy-Hill S, Taylor D. Using Virtual Reality to Provide Health Care Information to People With Intellectual Disabilities: Acceptability, Usability, and Potential Utility. J Med Internet Res 2011;13(4):e91 [FREE Full text] [doi: 10.2196/jmir.1917]
7. Klinger E, Chemin I, Lebreton S, Marié RM. Virtual action planning in Parkinson's disease: a control study. Cyberpsychol Behav 2006 Jun;9(3):342-347. [doi: 10.1089/cpb.2006.9.342] [Medline: 16780402]
8. Zhang L, Abreu BC, Masel B, Scheibel RS, Christiansen CH, Huddleston N, et al. Virtual reality in the assessment of selected cognitive function after brain injury. Am J Phys Med Rehabil 2001 Aug;80(8):597-604; quiz 605. [Medline: 11475481]
9. Campbell Z, Zakzanis KK, Jovanovski D, Joordens S, Mraz R, Graham SJ. Utilizing virtual reality to improve the ecological validity of clinical neuropsychology: an FMRI case study elucidating the neural basis of planning by comparing the Tower of London with a three-dimensional navigation task. Appl Neuropsychol 2009 Oct;16(4):295-306. [doi: 10.1080/09084280903297891] [Medline: 20183185]
10. Zakzanis KK, Quintin G, Graham SJ, Mraz R. Age and dementia related differences in spatial navigation within an immersive virtual environment. Med Sci Monit 2009 Apr;15(4):CR140-CR150. [Medline: 19333197]
11. Rizzo AA, Buckwalter JG, van der Zaag C. Virtual environment applications in clinical neuropsychology. In: Stanney K, editor. The Handbook of Virtual Environments. New York: Lawrence Erlbaum Associates; 2002:1027-1064.
12. Lo Priore C, Castelnuovo G, Liccione D, Liccione D. Experience with V-STORE: considerations on presence in virtual environments for effective neuropsychological rehabilitation of executive functions. Cyberpsychol Behav 2003 Jun;6(3):281-287. [doi: 10.1089/109493103322011579] [Medline: 12855084]
13. Koenig S, Crucian G, Dalrymple-Alford J, Dünser A. Assessing navigation in real and virtual environments: A validation study. 2010 Presented at: 8th International Conference on Disability, Virtual Reality and Associated Technologies; Aug 31-Sep 2, 2010; Viña del Mar/Valparaíso, Chile p. 7-16.
14. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. Gerontologist 1969;9(3):179-186. [Medline: 5349366]

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15. Souder E, Chastain JR, Williams RD. Dementia in the new millennium. Medsurg Nurs 2002 Apr;11(2):61-9; quiz 70. [Medline: 11962170]
16. Petersen RC. Mild cognitive impairment as a diagnostic entity. J Intern Med 2004 Sep;256(3):183-194. [doi: 10.1111/j.1365-2796.2004.01388.x] [Medline: 15324362]
17. Winblad B, Palmer K, Kivipelto M, Jelic V, Fratiglioni L, Wahlund LO, et al. Mild cognitive impairment--beyond controversies, towards a consensus: report of the International Working Group on Mild Cognitive Impairment. J Intern Med 2004 Sep;256(3):240-246. [doi: 10.1111/j.1365-2796.2004.01380.x] [Medline: 15324367]
18. Petersen RC, Smith GE, Waring SC, Ivnik RJ, Tangalos EG, Kokmen E. Mild cognitive impairment: clinical characterization and outcome. Arch Neurol 1999 Mar;56(3):303-308. [Medline: 10190820]
19. Nelson AP, O'Connor MG. Mild cognitive impairment: a neuropsychological perspective. CNS Spectr 2008 Jan;13(1):56-64. [Medline: 18204415]
20. Binegar DL, Hynan LS, Lacritz LH, Weiner MF, Cullum CM. Can a direct IADL measure detect deficits in persons with MCI? Curr Alzheimer Res 2009 Feb;6(1):48-51 [FREE Full text] [Medline: 19199874]
21. Amieva H, Letenneur L, Dartigues JF, Rouch-Leroyer I, Sourgen C, D'Alchée-Birée F, et al. Annual rate and predictors of conversion to dementia in subjects presenting mild cognitive impairment criteria defined according to a population-based study. Dement Geriatr Cogn Disord 2004;18(1):87-93. [doi: 10.1159/000077815] [Medline: 15087583]
22. Gauthier S, Reisberg B, Zaudig M, Petersen RC, Ritchie K, Broich K, International Psychogeriatric Association Expert Conference on mild cognitive impairment. Mild cognitive impairment. Lancet 2006 Apr 15;367(9518):1262-1270. [doi: 10.1016/S0140-6736(06)68542-5] [Medline: 16631882]
23. Petersen RC, Roberts RO, Knopman DS, Geda YE, Cha RH, Pankratz VS, et al. Prevalence of mild cognitive impairment is higher in men: The Mayo Clinic Study of Aging. Neurology 2010 Sep 06;75(10):889-897. [doi: 10.1212/WNL.0b013e3181f11d85]
24. Yesavage JA, O'Hara R, Kraemer H, Noda A, Taylor JL, Ferris S, et al. Modeling the prevalence and incidence of Alzheimer's disease and mild cognitive impairment. J Psychiatr Res 2002 Oct;36(5):281-286. [Medline: 12127595]
25. Bangen KJ. Complex activities of daily living vary by mild cognitive impairment subtype. Journal of the International Neuropsychological Society 2010;16:630-639. [doi: 10.1017/S1355617710000330]
26. Goldberg TE. Performance-based measures of everyday function in mild cognitive impairment. American Journal of Psychiatry 2010;167:845-853. [doi: 10.1176/appi.ajp.2010.09050692]
27. Burton CL, Strauss E, Bunce D, Hunter MA, Hultsch DF. Functional abilities in older adults with mild cognitive impairment. Gerontology 2009;55(5):570-581. [doi: 10.1159/000228918] [Medline: 19602873]
28. Bangen KJ, Jak AJ, Schiehser DM, Delano-Wood L, Tuminello E, Han SD, et al. Complex activities of daily living vary by mild cognitive impairment subtype. Journal of the International Neuropsychological Society 2010;16:630-639. [doi: 10.1017/S1355617710000330]
29. Aretouli E, Brandt J. Everyday functioning in mild cognitive impairment and its relationship with executive cognition. Int J Geriatr Psychiatry 2010 Mar;25(3):224-233 [FREE Full text] [doi: 10.1002/gps.2325] [Medline: 19650160]
30. Teng E, Becker BW, Woo E, Cummings JL, Lu PH. Subtle deficits in instrumental activities of daily living in subtypes of mild cognitive impairment. Dement Geriatr Cogn Disord 2010;30(3):189-197 [FREE Full text] [doi: 10.1159/000313540] [Medline: 20798539]
31. Teng E, Becker BW, Woo E, Knopman DS, Cummings JL, Lu PH. Utility of the Functional Activities Questionnaire for Distinguishing Mild Cognitive Impairment From Very Mild Alzheimer Disease. Alzheimer Dis Assoc Disord 2010 Jun 29:348-353 [FREE Full text] [doi: 10.1097/WAD.0b013e3181e2fc84] [Medline: 20592580]
32. Perneczky R, Pohl C, Sorg C, Hartmann J, Komossa K, Alexopoulos P, et al. Complex activities of daily living in mild cognitive impairment: conceptual and diagnostic issues. Age Ageing 2006 May;35(3):240-245 [FREE Full text] [doi: 10.1093/ageing/afj054] [Medline: 16513677]
33. Park B, Jun JK, Park J. Cognitive impairment and depression in the early 60s: which is more problematic in terms of instrumental activities of daily living? Geriatr Gerontol Int 2013 Apr 7. [doi: 10.1111/ggi.12055] [Medline: 23560396]
34. Tarnanas I, Harper B, Majer A, Testerman R. World Intellectual Property Organization: Patentscope. 2009. Virtual Reality Interface System, EPO patent WO2010075481 URL: http://patentscope.wipo.int/search/en/WO2010075481 [accessed 2013-07-30] [WebCite Cache ID 6IUw2U6aI]
35. Perneczky R, Pohl C, Sorg C, Hartmann J, Tosic N, Grimmer T, et al. Impairment of activities of daily living requiring memory or complex reasoning as part of the MCI syndrome. Int J Geriatr Psychiatry 2006 Feb;21(2):158-162. [doi: 10.1002/gps.1444] [Medline: 16416470]
36. Rahimi F, Duval C, Jog M, Bee C, South A, Jog M, et al. Capturing whole-body mobility of patients with Parkinson disease using inertial motion sensors: expected challenges and rewards. Conf Proc IEEE Eng Med Biol Soc 2011;2011:5833-5838. [doi: 10.1109/IEMBS.2011.6091443] [Medline: 22255666]
37. Yamaguchi DA, Foloppe P, Richard E, Allain P. A dual-modal virtual reality kitchen for (re)learning of everyday cooking activities in Alzheimer's disease. Presence: Teleoperators and Virtual Environments 2012:43-57. [doi: 10.1162/PRESa00080]

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38. Sheikh JI, Yesavage JA. Geriatric Depression Scale (GDS). Recent evidence and development of a shorter version. In: Brink TL, editor. Clinical Gerontology: A Guide to Assessment and Intervention. New York: The Haworth Press; 1986:165-173.
39. Visser PJ, Verhey FR, Boada M, Bullock R, De Deyn PP, Frisoni GB, et al. Development of screening guidelines and clinical criteria for predementia Alzheimer's disease. The DESCRIPA Study. Neuroepidemiology 2008;30(4):254-265 [FREE Full text] [doi: 10.1159/000135644] [Medline: 18515975]
40. Dodge H, Mattek N, Austin D, Hayes T. In-home walking speeds and variability trajectories associated with mild cognitive impairment. Neurology 2012;78(24):1946-1952. [doi: 10.1212/WNL.0b013e318259e1de]
41. Laird NM, Ware JH. Random-effects models for longitudinal data. Biometrics 1982 Dec;38(4):963-974. [Medline: 7168798]
42. Tukey JW. The philosophy of multiple comparisons. Statist Sci 1991 Feb;6(1):100-116. [doi: 10.1214/ss/1177011945]
43. Akobeng AK. Understanding diagnostic tests 3: Receiver operating characteristic curves. Acta Paediatr 2007 May;96(5):644-647. [doi: 10.1111/j.1651-2227.2006.00178.x] [Medline: 17376185]
44. Slavin M, Brodaty H, Kochan N, Crawford JD, Trollor J, Draper B, et al. Prevalence and predictors of “subjective cognitive complaints” in the Sydney Memory and Ageing Study. Am J Geriatr Psychiatry 2010 Aug;18(8):701-710. [Medline: 21491631]
45. Simoes M, Castro L, Ribeiro O, Salgado T, Paz C. P03-94 Subjective Memory Complaints and Mild Cognitive Impairment. European Psychiatry 2009 Jan;24:S1093. [doi: 10.1016/S0924-9338(09)71326-4]
46. Leonardi C, Mennecozzi C, Not E, Pianesi R, Zancanaro M. Designing a familiar technology for elderly people. Gerontechnology 2008;7(2):151. [doi: 10.4017/gt.2008.07.02.088.00]
47. Slater M. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. Philos Trans R Soc Lond B Biol Sci 2009 Dec 12;364(1535):3549-3557 [FREE Full text] [doi: 10.1098/rstb.2009.0138] [Medline: 19884149]

Abbreviations

AD: Alzheimer disease
ADL: Activities of Daily Living
AUC: area under the curve
BADL: basic activities of daily living
GDS: geriatric depression scale
IADL: instrumental activities of daily living
MANOVA: multivariate analyses of variance
MCI: mild cognitive impairment
MMSE: mini-mental state examination
RAVLT: Rey Auditory Verbal Learning Test
ROC: receiver-operating curve
RR: relative risk
UI: user interface
VE: virtual environment
VR: virtual reality
VR-DOT: Virtual Reality Day-Out Task
VRPN: virtual reality peripheral network

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