RESEARCH ARTICLE

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Evaluation of a virtual reality-based memory training programme for Hong Kong Chinese older adults with questionable dementia: a pilot study

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Background: Older adults with questionable dementia are at risk of progressing to dementia, and early intervention is considered important. The present study investigated the effectiveness of a virtual reality (VR)-based memory training for older adults with questionable dementia.

Methods: A pre-test and post-test design was adopted. Twenty and 24 older adults with questionable dementia were randomly assigned to a VR-based and a therapist-led memory training group, respectively. Primary outcome measures included the Multifactorial Memory Questionnaire and Fuld Object Memory Evaluation.

Results: Both groups demonstrated positive training effects, with the VR group showing greater improvement in objective memory performance and the non-VR group showing better subjective memory subtest results in the Multifactorial Memory Questionnaire.

Conclusion: The use of VR seems to be acceptable for older adults with questionable dementia. Further study on the effect of educational background and memory training modality (visual, auditory) is warranted. Copyright © 2011 John Wiley & Sons, Ltd.

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Introduction

Dementia is a major cause of disability and accounts for a considerable proportion of health care expenditure in developed countries (Whitehouse *et al.*, 1993). Dementia of the Alzheimer type is reported to be the most frequently diagnosed subcategory and accounts for 75% of all dementia diagnoses confirmed at post-mortem examination (Brayne, 1994). Older adults whose performance was between the normal and dementia were broadly defined as "questionable dementia" (Devanand *et al.*, 1997) and can be determined by the Clinical Dementia Rating (CDR) scale, which is a semi-structured interview. There is a need for early detection, diagnosis, and treatment (Bell-McGrinty *et al.*, 2002). Strategy use was positively correlated with the objective memory performance of older people (Chung and Man, 2009).

An effective design of intervention programmes should ensure successful encoding and retrieval. The present study thus proposed a memory training programme using a cutting-edge computer technology (virtual-reality) for older adults with questionable dementia. This innovative method was assumed to lessen cognitive decline by providing cognitive support in the encoding and retrieval processes of memory.

Virtual reality (VR) can be of two types: immersive and non-immersive. In the present study, the non-immersive form of VR was used. The visual aspects of the environment are presented to the user on a PC monitor and the auditory array is presented through speakers. VR has been used with people with dementia (van Schaik *et al.*, 2008). As VR environments are precisely controlled and can deliver graded training

according to the level of performance, entirely safe environments can be provided within which the learning outcomes and behaviour of older adults with mild cognitive impairment (MCI) can be minutely monitored. Moreover, use of VR serves as a form of cognitive load reduction, which can be beneficial to persons with MCI, decreasing the required attentional resource and preventing overloading by simplified handling (Grealy *et al.*, 1999).

In the present study, development of VR programme was theoretically driven and delineated with guiding principles; for example, memory performance is facilitated by using multiple sensory modalities at encoding and spaced retrieval strategies to facilitate memory function (Camp, 2006). The participant should also enact the target task (Bird and Kinsella, 1996) and personalize a task by allowing the participants to make choices. Specifically, the two study objectives were (1) to develop and implement a non-immersive VR-based memory training programme for older adults with questionable dementia, and (2) to examine the efficacy of a VR memory training programme on episodic memory and self-appraisal of cognitive functions as compared with a conventional therapist-led memory training programme. The study presents two hypotheses: (1) Positive changes would be exhibited in the VR-based and therapist-led memory training. (2) The VR-based memory group show better memory functions and greater functional independence as compared with the therapist-led group.

Methods

Participants

Community-dwelling cognitively impaired older adults were recruited by convenience sampling from the Alzheimer's Disease Association, memory clinics, a self-help group for persons with memory impairment, and a community service setting called the Neighbourhood Advice-Action Council in Hong Kong. Selection criteria for eligibility included age 65 years or above, having subjective memory complaints, and being classified as having questionable dementia as determined (Morris *et al.*, 2001) by a score of 0.5 in the CDR scale (Hughes *et al.*, 1982. The CDR scale is a semi-structured interview that indicates five global ratings (0, normal; 0.5, questionable dementia; 1, mild dementia; 2, moderate dementia; 3, severe dementia). In addition, the Chinese version of the Mini Mental State Examination (CMMSE) was also used (Folstein *et al.*, 1975; Chiu *et al.*, 1994). The CMMSE cut-off score would be adjusted according to the educational level of the participants, as poor education tends to lead to a lower median MMSE score (Crum *et al.*, 1993). They should demonstrate a basic attention span of 3 min or more (e.g., able to follow a daily conversation) and medical stability. Thus, a score between 18 and 25 was adopted (cut-off for those with middle school or higher education, <25; those with elementary education, <21; and those with no schooling, <18). Exclusion criteria included severe visual impairment, impaired physical functions inhibiting operation of a keyboard or a mouse, clinical depression (as reflected by the Chinese version of Geriatric Depression Scale; Wong *et al.*, 2002), pre-morbid and profound post-morbid mental retardation, and other neurological pathologies (epilepsy). Forty-four eligible participants were enrolled in the study and randomly allocated, by drawing lots, to either a VR group ($n = 20$) or a therapist-led group ($n = 24$).

Procedures

Ethical approval was sought from the Ethical Committee of the Hong Kong Polytechnic University before a face-to-face interview was carried out to explain the purpose of the study and to explore the participant's suitability for the study. Written consent was also obtained before assessment and training were carried out. A pretest–post-test design was adopted in this study. Both the VR and therapist-led training programmes consisted of 10 individual sessions of 30 min each, which were run two to three times a week. The two programmes were conducted independently by two occupational therapists, and assessments were conducted by another independent rater. For the VR group, 5 to 10 min was given to participants to practise the use of a joystick or a keyboard. Warm-up exercises were also given to participants in the first three sessions to familiarize them with the VR environment and simple computer operations. They would use either the joystick or the direction buttons of the keyboard to control the navigation action and give responses to a memory task. The therapist only provided stand-up supervision and assistance when needed. For the therapist-led group, warm-up exercises on using a training manual were also given, and training was delivered through a psycho-educational approach. The training material was a manual of questions to remember and answers to recall. Teaching was administered by an occupational therapist on an individual basis throughout the training period.

Instrumentation. Three screening assessment tools were used in the recruitment of participants.

(1) CDR scale. The CDR scale has been widely used as a global assessment instrument for clinical practice and research to indicate the staging of dementia severity (Hughes *et al.*, 1982; Morris, 1993). It consists of six cognitive domains (memory, orientation, judgement and problem solving, community affairs, home and hobbies, personal care). Each domain is rated on a five-point scale from 0 (no impairment) over 0.5 (questionable impairment) to 3 (maximum impairment). All six ratings will form an overall score ranging from 0 (no impairment) to 3 (severe impairment). A CDR scale score of 0.5 indicates questionable dementia or very mild dementia. In the present study, all participants had a CDR scale score of 0.5.
(2) Mini Mental State Examination (MMSE). The MMSE was developed by Folstein's group (Folstein *et al.*, 1975). A validated Chinese version of MMSE (CMMSE) (Chiu *et al.*, 1994) was used in the present study. It assesses memory, orientation, visual-spatial copying, and language and is a well-known screening test for a wide range of cognitive disabilities. The MMSE has recently been used as a screening test for Alzheimer's disease. The reported sensitivity is 97.5% and the specificity is 97.3%. The test–retest reliability is 0.78 and the inter-rater reliability is 0.99. With reference to the educational level of the older adults, different cut-off scores were used (score range, 0–30; the higher the score, the better cognitive performance): a score of 22 or below for those with more than 2 years of education, a score of 20 for those with 1 to 2 years of education, and a score of 18 or below for those with no education. In the present study, all participants had a score of 19 or above.
(3) Geriatric Depression Scale (Yesavage *et al.*, 1983). The Geriatric Depression Scale is a widely used screening test for depression. A shorter 15-item Chinese version was employed (Lee *et al.*, 1994) and a validated Cantonese version of GDS-15 was adopted (Wong *et al.*, 2002) in the present study. It has been validated in Chinese populations with high sensitivity and specificity using a cut-off point of 8 (Chiu *et al.*, 1994) for a score range of 0–15. Higher score indicates possibility of clinical depression. It is useful in people with mild to moderate cognitive impairment (O'Riordan *et al.*, 1990). In the present study, all participants did not show clinical depression.

Primary outcome measures used for the pre-test and post-test evaluation.

(1) Multifactorial Memory Questionnaire (MMQ; Troyer and Rich, 2002). The Chinese version of the MMQ was used. It evaluates self-appraised memory and cognitive function in three dimensions: (a) contentment with one's own memory ability; (b) subjective perception of memory ability in everyday functioning; and (c) self-reported use of memory and cognitive strategies. The MMQ-contentment contains 18 statements measuring the participant's level of satisfaction with his or her own memory ability (e.g., "I have confidence in my ability to remember things") and is rated by the level of agreement (0, strongly disagree; 4, strongly agree). The MMQ-ability consists of 20 everyday situations in which the participants appraise their memory ability over the past 2 weeks (e.g., "How often do you forget an appointment?") and is evaluated by the frequency of mistakes made (0, always; 4, never). The MMQ-strategy contains 18 memory strategies (e.g., "How often do you write things on a calendar?") where the participants rated the frequency of strategy use over the past 2 weeks (0, never; 4, always). Satisfactory psychometric properties of the MMQ including reliability and construct validity were demonstrated. A significant and moderate association has been reported between MMQ-contentment and MMQ-ability ($r = 0.62$).
(2) Fuld Object Memory Evaluation (FOME; Fuld, 1977). FOME is a measure of episodic memory function, including encoding, immediate and longer-term retrieval, and recognition. It is similar to list-learning tasks except that the items to be remembered are presented in the form of real objects. At the beginning of the assessment, the participants were asked to encode 10 unrelated items (e.g., glass, ball, pin) by touch, vision, and naming. Afterwards, the participants were asked to recall these items across five trials and at an interval of 20 min after the fifth trial. The total encoding score (0–50), total retrieval score (0–50), and delayed recall score (0–10) were used for analysis in this study. The psychometric properties of the FOME have been established for community-dwelling Hong Kong Chinese people (Chung, 2009). The optimal cut-off scores suggested for total retrieval and delayed recall were 31 and 7, respectively, in differentiating dementia from normal cognitive functioning. The performance of the FOME was not affected by the educational

level and reading ability of the participants (Mast *et al.*, 2001; Chung, 2009).

(3) Hong Kong Chinese version of the Lawton Instrumental Activities of Daily Living (HK Lawton IADL) scale (Lawton and Brody, 1969; Tong and Man, 2002). The HK Lawton IADL scale was used, and the scale includes aspects of community-living skills such as cooking, use of telephone, use of transport, household management, money management, and shopping skills. There is a full score of 27 points for rating nine items of community-living skills.

VR and therapist-led programmes. A non-immersive VR-based memory training programme and a non-VR programme were developed using the same scenarios: a home setting and a convenience shop (Figure 1). Each scenario was designed according to a gradation structure: tasks ranged from simple to more complex in terms of the number and similarity of objects to be remembered as well as the duration of distraction. The training was also upgraded systematically according to (a) duration of recall according to the spaced retrieval technique (Thivierge *et al.*, 2008); (b) types of memory stimuli delivered: from visual-auditory and visual only to auditory only; and (c) migration from semantic to episodic memory, by requiring the participants to gradually remember what to do and the sequence of actions. The VR programme was expected to achieve better encoding of information by the multimedia nature of the training, better recall of newly learned information by spaced retrieval, and motivation for persistent training through the subjective "presence" or the subjective feeling of being present in a simulated environment (Aguinis *et al.*, 2001).

The home setting consisted of two bedrooms, one living room, one dining room, a kitchen, and a bathroom. For instance, during training, each participant would be given instructions by both verbal and written messages displayed by the computer. He or she would be told about a 3-min task involving moving around, reading, and memorizing the items on a memo pad placed on the table within the living room. They then took out those items from the refrigerator in the kitchen after a period of distraction. The time taken to finish the task was recorded.

The shop scenario was a simulated convenience shop consisting of six goods trays, one fruit tray, six refrigerators, and one cashier. Participants were asked to search around the shop and buy the requested items (Figure 2). Similar to the home scenario, they used the joystick or the direction buttons of the keyboard to control the "walk around" within the virtual shop to find and pick the correct items. To finish the task, participants were requested to pay their bills to the cashier. Support was given to reinforce encoding and retrieval by verbal prompting and appearance of a staff member asking for payment. This also signified the completion of a training session, and the total time taken was recorded.

The therapist-led training adopted a psychoeducational approach and was very similar to the VR, but with colour-print images that matched the VR images. The learning of the VR-programme was supervised by a therapist, with similar content, structure, and frequency of memory training. The participants learned through paper-and-pencil tasks instead of using the computer-based VR technology. Figure 3 shows a sample memory training sheet showing the objects to be memorized and a sample answer sheet showing the objects to be memorized and distracters.

Data analysis

The independent variables of the present study were two memory training programmes in enhancing

a **b**

Figure 1 (a) Living room; (b) convenience shop.

Figure 2 Scenarios within the convenience shop.

community-living skills for persons with MCI. Two-way analysis of covariance (ANCOVA) was also used to get an overall picture of the training effect.

Results

Table 1 shows a summary of the demographic characteristics, screening, and pre- and post-training outcome measures of the two intervention programmes. Baseline measurements showed that there were no statistically significant differences between the VR and non-VR groups in age ($t = 0.080$, $p = 0.994$), gender ($\chi^2 = 0.003$, $p = 0.954$), educational level ($\chi^2 = 5.788$, $p = 0.055$), and depression level ($t = -0.198$, $p = 0.845$). All participants' CDR scale scores were 0.5 and thus demonstrated questionable dementia. The groups' cognitive status and functional independence were considered to be very similar (CMMSE: $t = -1.540$, $p = 0.133$; HK Lawton IADL: $t = 1.450$, $p = 0.156$). There were no between-group differences in baseline outcome measures except for the FOME total encoding score ($t = -2.650$, $p = 0.008$) and delayed recall score ($t = -2.450$, $p = 0.005$). This was also reflected by a higher baseline in FOME (encoding) for the therapist-led group and a higher baseline in FOME (delay scores) for the VR group.

The results of the two-way repeated measures ANCOVA (FOME-total encoding and FOME-delayed recall as covariates) are shown in Table 2. A significant interaction effect (time and group) was found for FOME (total recall), FOME (delayed recall), and MMQ (contentment). A significant main effect of time was found for all FOME subscales and the three MMQ subscales, whereas a significant main effect of group was found for FOME (total recall, delayed recall) and MMQ (contentment). Within-group analysis showed

Figure 3 Samples of memory sheet and answer sheet (circle the right objects) of the non-VR programme.

Table 1 Summary of demographics, screening, and outcome measures of the VR and therapist-led groups

VR	VR group ($n = 20$)		Therapist-led group ($n = 14$)	
Gender, *n* (%)				
Male	3 (15)		2 (8.4)	
Female	17 (85)		22 (91.6)	
Level of education, *n* (%)				
<1 year	16 (80)		14 (58.4)	
1–2 years	2 (10)		4 (16.6)	
>2 years	2 (10)		6 (25.0)	
Mean age (SD), years	80.30 (1.21)		80.28 (1.31)	
Screening tests (max. score)				
CMMSE (0–30)	21.05 (3.79)		23.00 (3.96)	
GDS (0–15)	7.96 (3.20)		6.47 (3.52)	
Outcome measures (max. score)				
	Pre-training Mean (SD)	Post-training Mean (SD)	Pre-training Mean (SD)	Post-training Mean (SD)
FOME-TE (50)	37.25 (3.10)	41.10 (6.01)	41.57 (6.29)	42.42 (3.87)
FOME-TR (50)	29.60 (5.01)	41.40 (5.68)	31.14 (9.23)	35.28 (3.49)
FOME-DR (10)	9.15 (0.81)	10.00 (0.00)	8.14 (1.56)	10.00 (0.00)
MMQ-contentment (68)	36.00 (9.45)	36.25 (6.17)	40.28 (9.32)	44.71 (5.91)
MMQ-ability (80)	49.60 (11.74)	50.65 (5.57)	54.00 (13.41)	55.71 (13.41)
MMQ-strategy (72)	15.30 (7.90)	21.45 (10.45)	14.42 (5.73)	15.28 (5.78)
HK Lawton IADL (27)	23.70 (3.48)	23.70 (2.43)	21.85 (4.72)	23.14 (2.41)

CMMSE, Cantonese version of Mini-Mental State Examination (higher score implies better cognitive function); GDS, Geriatric Depression Scale (lower score means better mood); FOME-TE, Fuld Object Memory Evaluation—total encoding (higher score implies better encoding); TR, total retrieval; DR, delayed recall (total retention recall) (higher score suggests better retrieval ability); MMQ, Multifactorial Memory Questionnaire (higher score implies better use of ability and strategy); HK Lawton IADL, Hong Kong Chinese version of the Lawton Instrumental Activities of Daily Living scale (higher score implies better IADL).

Table 2 Results of two-way repeated measures ANCOVA

	Time effect		Group effect		Time and group interaction effect	
	F	*p*	*F*	*p*	*F*	*p*
FOME-TE	15.86	<0.001**	0.005	0.944	0.005	0.944
FOME-TR	84.86	<0.001**	12.93	0.001*	12.93	0.001*
FOME-DR	4.27	0.047*	8.62	0.001*	8.62	0.001*
MMQ-contentment	50.44	<0.001**	14.09	0.001*	14.09	0.001*
MMQ-ability	21.90	<0.001**	3.18	0.084	3.18	0.084
MMQ-strategy	4.23	0.048*	2.50	0.06	2.41	0.06

*$p < 0.05$.
**$p < 0.001$.

that the VR group demonstrated significant improvement in all three FOME scores (total encoding, total recall, delayed recall) and MMQ-strategy, whereas the therapist-led group showed significant improvement in FOME (total recall, delayed recall) and MMQ-contentment (Table 2).

Discussion

This study examined the clinical efficacy of a memory training programme delivered in either a VR or a therapist-led mode for older adults with MCI. The findings concur with the results of previous studies that the incorporation of successful memory techniques such as spaced retrieval (Ozgis *et al.*, 2009), encoding support (Multhaup and Balota, 1997), retrieval strategies (Bäckman and Herlitz, 1996), and requiring the participants to engage in cognitive activities during encoding (Lipinska and Bäckman, 1997) can be effective means of supporting MCI to maintain their memory function.

The results of the within-group analysis suggest that participants of both the VR and therapist-led groups

benefited from the memory training programme by demonstrating significant improvement in list recall (immediate and delayed) at post-intervention. For the VR group, significant improvement was also shown in the encoding functioning of episodic information (a word list in this study). This finding suggests that a virtual learning environment that is supplemented with enriched audio-visual stimuli may enhance information encoding.

The VR group had a higher percentage of older adults with lower level of education but showed greater improvement than the non-VR group (higher percentage of better education). This is interesting because one would expect older people with less education to cope less with VR, but they appear to benefit more from the VR than the non-VR training. This might be a way of targeting where most benefit could occur. In other words, in future studies, it is worth to explore further if VR works better in older adults with questionable dementia and with less education.

In terms of subjective perception of memory functioning, the VR group perceived better use of memory strategies, whereas the non-VR group reported better contentment with memory performance. This selective difference hints that in the non-VR training, the presence of a therapist to administer the training programme may have provided individualized support and verbal reinforcement to the study participants, who therefore felt more satisfied with their memory performance after the training. On the other hand, the VR training has the advantage of providing a self-pacing learning mode and a non-threatening training medium that may facilitate the participants' acquisition of a memory strategy (Tam and Man, 2004). The VR group also commended the use of computer training in reinforcing their memory strategies. This finding was in line with other memory training programmes for older adults with MCI (Troyer *et al.*, 2008). This suggests that the use of memory strategies might be best achieved through well-controlled computerized programmes, through active and higher degrees of participation, and by putting knowledge into practice, which were common to both training.

When comparing the differential benefits of the two memory training programmes (VR versus non-VR), the findings suggest that the VR training programme led to significantly more gains in objective memory performance, in particular immediate recall and delayed recall of episodic memory. The use of multiple sensory modalities in a virtual environment and better focus of attention (Munro *et al.*, 2002) may partly explain the improvement. Previous studies also suggested that the VR training medium reduced the cognitive load by eliminating the need to convert two-dimensional training materials into three-dimensional representation that enables users to focus more cognitive resources on learning the task (Johnson and Hyde, 1997). Usability and motivational factors (Priore *et al.*, 2003), better sense of control over memory abilities (Lachman, 2000), real-time interaction with the system (Bird and Kinsella, 1996), and feedback received on own performance (Riva, 2002) may also contribute to the success of the VR memory training in objective memory functioning.

In terms of subjective appraisal of memory functioning, the non-VR group reported significantly better contentment with memory performance compared with the VR group. It was postulated that the therapist-led group might have been given better reassurance about the training through emotional support from the therapist. This kind of "personal touch" has been supported in similar studies using computers in cognitive rehabilitation (Man *et al.*, 2006).

This study has some inherent limitations requiring attention. One of the limitations is the small number of participants. Also, there was no follow-up analysis. The training was considered short in duration and low in frequency (Rapp *et al.*, 2002; Talassi *et al.*, 2007). A number of issues were related to the methodology. Because we used a community sample of older adults with subjective memory complaints, it is consequently likely that some of them had questionable dementia whereas others were normally ageing and might not even have early dementia. The objective memory test was used in the visual domain, and verbal memory was not examined. Because both training groups improved, the effect size presented may be the result of practice effect in addition to the effect of either of the interventions; one should be careful in interpreting results or drawing conclusions.

Conflict of interest

The authors had no conflict of interests during any part of the study.

Key points

- The usability and effective use of virtual reality for older adults with questionable dementia was initially supported.
- Further study on the effect of educational background and training modality (visual or auditory) is warranted.

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