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PERSPECTIVE PIECE


# THE POTENTIAL VALUE OF VIRTUAL ENVIRONMENTS (VES) IN REHABILITATION

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## The Potential Value of Virtual Environments (VEs) in Rehabilitation

Virtual Environments (VEs) are computer-generated immersive, interactive simulations.[1] These controlled settings can be designed to enable assessment and training of a wide variety of daily tasks, including those that are difficult to practice in the real-world for practical and safety reasons.[2,3] The use of VEs has attracted increased interest as shown by increasing publications in the realm of rehabilitation. VEs are especially promising in the area of rehabilitation of instrumental activities of daily living (IADLs).[4] Despite this recent growth in research, the use of these technologies lacks the validation necessary to establish them as standard practices in rehabilitation. Given the growing use and potential of VEs in rehabilitation, there is a need for specific guidelines to be established for the validity testing of these constructs.

## Advantages of VEs

Rehabilitation necessitates extensive practice, feedback, detailed instruction, and strategy implementation, typically requiring multiple visits to a clinician.[5] The patient must not only invest the time of treatment session but also the time and expense of traveling to and from the therapist's office. The logistics of travel may be particularly troublesome for those with involved disabilities. Often, the recommended course of face to face therapy is prohibitively impractical, and the limited therapy provided is not effective.[6] Virtual Environments may be designed to be engaged in at home via an individual's personal computer, providing a mechanism for many more opportunities for practice and strategy formation while eliminating the barrier of travel.[7]

## Three Existing Virtual Environments (VEs) Showing Potential for Use in Rehabilitation

### *VMall*

Among the virtual shopping malls that have been developed, one of the most thoroughly described and tested is one developed by Rand and colleagues.[4,8,9] This mall is called the VMall and is described in detail by Rand and colleagues in their 2007 article.[4] It has been tested for use in rehabilitation. One especially unique and innovative feature of the mall is that the individual participating in the shopping experience actually appears in the mall, which consists of nine aisles.[8]

In a critical study, Rand and colleagues tested the ecological and construct validity of tasks on the Virtual Multiple Errands Test (VMET) when performed in the VMall.[8] To help establish ecological validity, participants' VMET scores (obtained in the virtual store) were compared to their scores on the Multiple Errands Test-Hospital Version (MET-HV) (scores obtained in the real hospital store). To study evidence of construct validity, scores on the VMET were also compared to scores on two established tests, the Zoo Map subtest of the Behavioral Assessment of Dysexecutive Syndrome (BADS) and an Instrumental Activities of Daily Living (IADL) questionnaire. Correlations between VMET and MET-HV scores were high for total number of mistakes, partial mistakes, and non-efficiency mistakes. Strong relationships were also found between the scores of the VMET and MET-HV and Zoo Map and IADL measures.

### *V-STORE*

A second virtual store, the V-STORE was developed by Lo Priore and colleagues in 2002.[6] Its

features were designed to assess similar constructs as established tests such as the Tower of London Test and the Wisconsin Card Sorting Test (WCST). In the V-STORE the patient's challenge is to solve a sequence of tasks, ordered in six levels of increasing complexity. Tasks are designed to require problem solving, behavioral control, memory and attention. Uniquely, a series of distracting elements have been added to the tasks.[6]

One pilot study[6] compared feelings of engagement experienced by twelve normal subjects to versions of the V-STORE that were designed to be more immersive (three dimensional with head mounted display and tracking device) or less immersive (flat screen). Three different measures were obtained: psychophysiological responses (GSR, skin conductance), a test of incidental recall memory related to auditory information coming from the outside environment, and a self-report questionnaire relating to feelings during and after the experience in the store.[6] For GSR, subjects of both groups showed an increase in GSR response while completing the tasks, however, the increase was significantly higher for the head-mounted display group. The number of questions answered correctly about events in the outside environment was less for the HMD group. This was thought to represent a deeper involvement in the virtual environment. There were no differences between the groups on the self-report questionnaire.

### *The Virtual Supermarket*

Lee and colleagues developed a virtual supermarket environment in 2003[10] for assessing and training activities of daily living. Unique features of this environment include four display stands and refrigerators that open both from the top and the front. Participants pick up objects by moving the cursor over the object, which will then change color, and pressing the joystick button. The joystick utilized by participants is a Joystick (Airstik 2000) (See Figure 1). To open the refrigerators, the participant must in a similar manner move to in front of the door using the joystick and press the joystick button. After opening a refrigerator door, objects may be selected from the refrigerator. Tasks in the virtual supermarket include navigating and exploring the supermarket, picking up goods at the supermarket and placing them in the cart, and exiting the supermarket.[10]

In a study of the virtual supermarket conducted by Lee and colleagues,[10] five participants who were receiving rehabilitation treatment participated.

**Figure 1**: Joystick.

Time elapsed, distance moved, and numbers of collisions with walls were recorded. In addition the number of goods selected, number of doors open, number of joystick button presses, and error rate were obtained for each participant. Next, participants completed the Immersive Tendencies Questionnaire (ITQ), the Simulator Sickness Questionnaire (SSQ), the Presence Questionnaire (PQ), and the Virtual Reality Questionnaire (VRQ). Participants returned for four additional sessions in the virtual supermarket. The time, distance, and number of collisions with walls tended to decrease with the number of sessions. The number of goods selected and number of joystick button presses tended to increase with time. Participants reported on the questionnaires that they could not control the joystick well during the experience and had difficulty navigating in the store.

### *Future of Virtual Environments (VEs) in Rehabilitation*

What is the future for Virtual Environments (VEs) in rehabilitation? There is great potential for using VEs in assessment and treatment. First, we have only begun to test the use of Virtual Environments (VEs) with a few populations with impairments, mainly stroke and traumatic brain injury. There are

many diagnoses, including multiple sclerosis, for whom VEs might be especially effective in treatment.[11] To best facilitate rehabilitation development of different environments is needed. For example, practicing strategies that might be performed in the home in a VE might be useful to assess suitability to live independently and also help train habits most likely to ensure home safety. Also, busy stores, the dentist, the doctor's office, or the department of motor vehicles might be most suitable for some individuals to practice in virtually. Furthermore, the development of diverse challenges within each environment is needed. Some tasks might require navigation of novel routes, others might require planning a daily schedule, or performing a sequence of steps. The end goal would be to build a corpus of tasks in multiple challenging environments that would be appropriately tailored for each individual.

Once virtual environments are created their use might be extended to build mobile applications which can be deployed on mobile phones and tablets. Once successful and safe performance is obtained in the virtual environment (presented on screen in the home or clinic location), use of the mobile extension app might allow the individual/client to go into the actual environment while still receiving support and cues from a remote clinician or assistant. This way grading the experience until the ultimate goal is obtained. See Figure 2. While there are deficiencies in current available software, rapid advances in the field of technology related to rehabilitation are making these goals more and more achievable.

### *Strategies for Validity Testing of Virtual Environments (VEs)*

A protocol is needed for testing the validity of tasks performed in VEs. First, face validity, the degree to which an assessment appears to be evaluating what it intends to measure,[4,12–15] would need to be

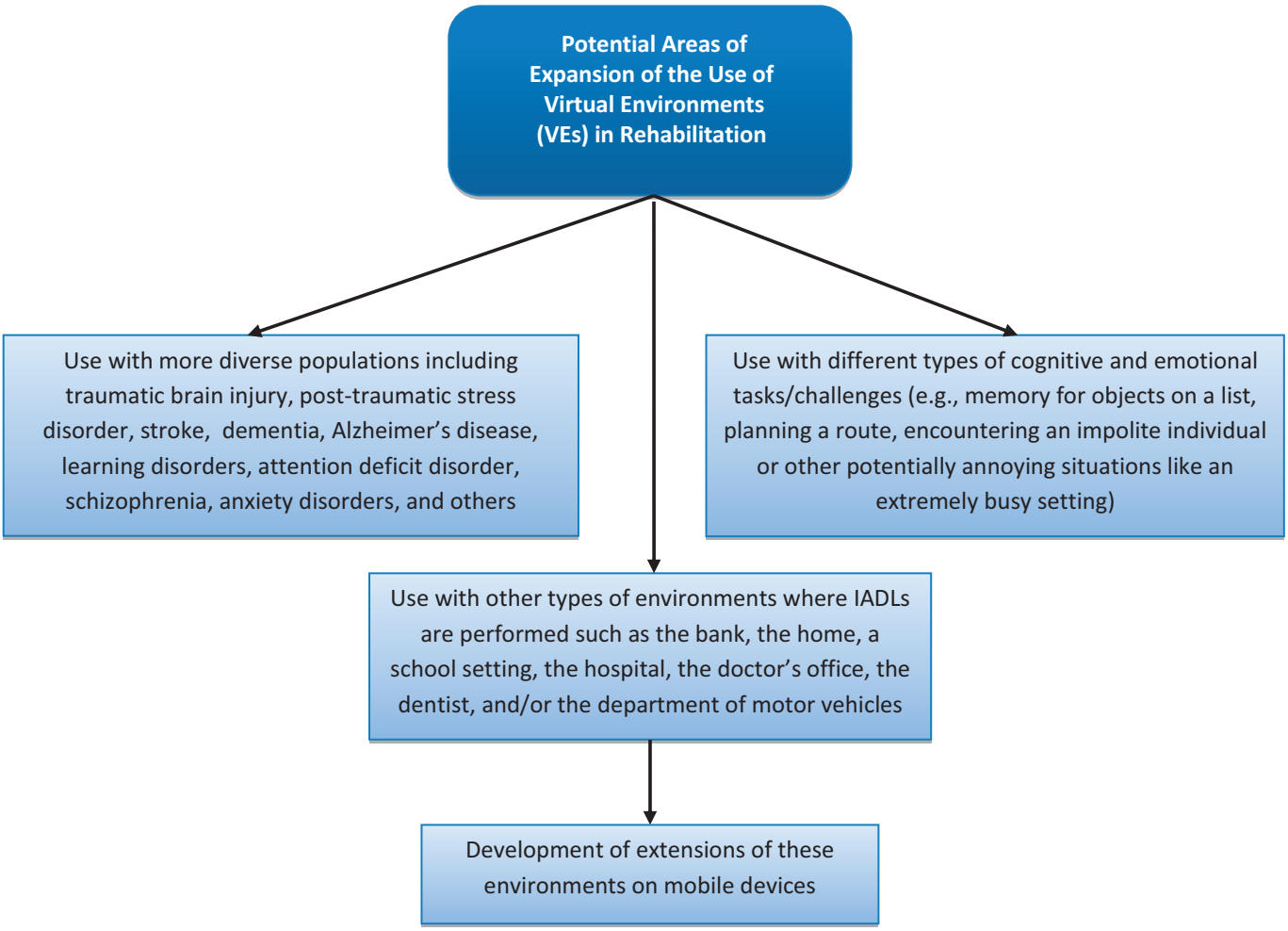


**Figure 2**: Potential Areas of Expansion of the Use of Virtual Environments in Rehabilitation.

established. This is typically done through the use of focus groups initially with clinicians/experts and then with affected individuals.[16–18] With VEs this would entail clinicians/experts going through the tasks in the environment themselves and evaluating, perhaps in the form of a survey or a group/individual meeting, the appropriateness of the difficulty and content of the tasks. Following this, the same type of assessment of the tasks in the environment would be completed by the end user (i.e. the patient).

Next, external validity, also referred to as generalizability would need to be assessed. This type of validity implies the ability to generalize to other situations, contexts, or people.[12] It is essential to

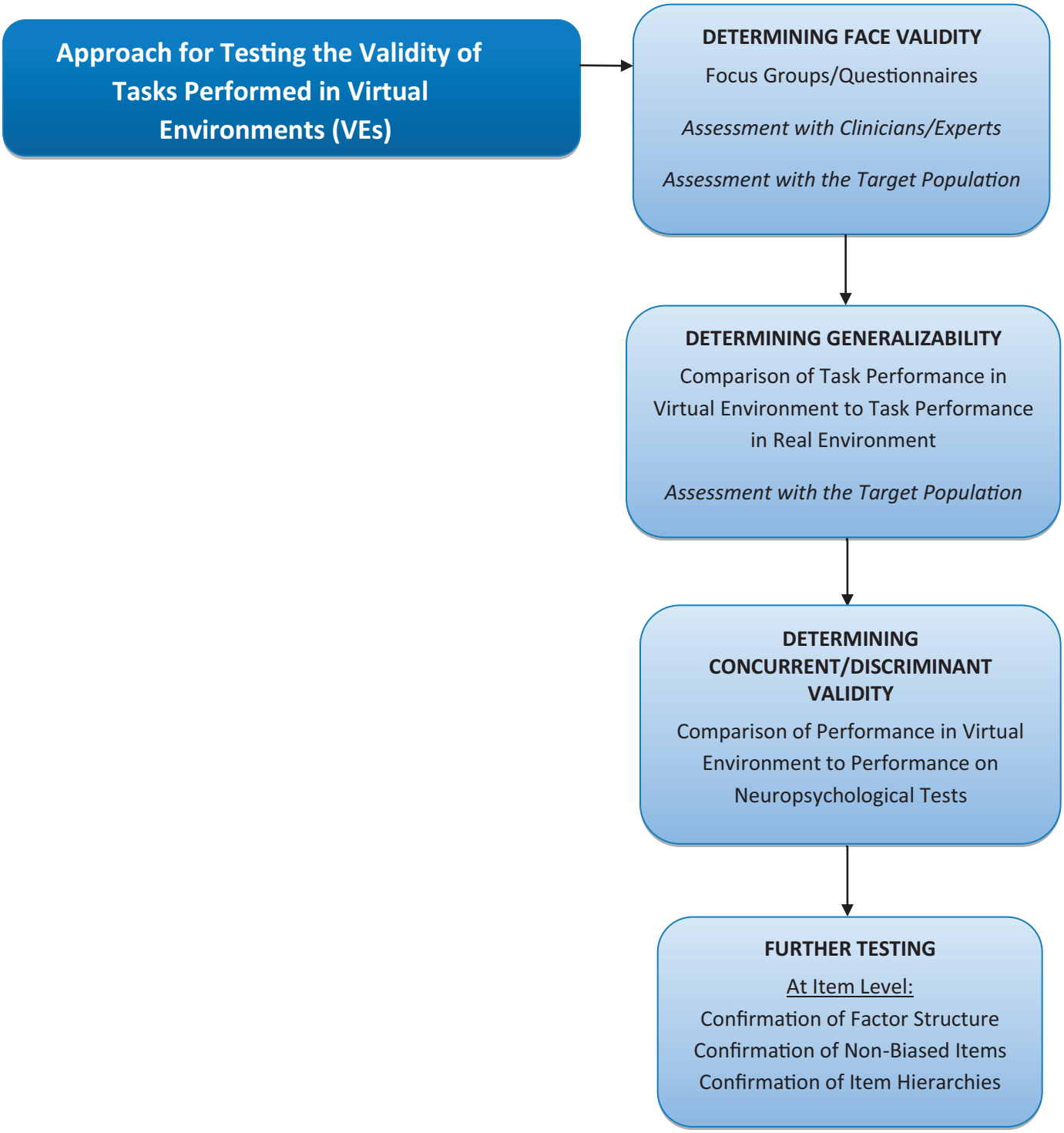


**Figure 3**: Suggested Approach for Testing the Validity of Tasks Performed in Virtual Environments.

verify that results produced in simulated environments are similar to those in the real world.[8,19] Assessing external validity would involve having affected individuals complete tasks both in the virtual and real environments and comparing performance in both settings. Similar performance would indicate that the virtual world was an accurate depiction of the actual one.

Finally, concurrent and discriminant validity should be ascertained. Concurrent validity determines if the results correlate well with measures of similar constructs. Discriminate validity addresses the extent to which performance on tasks is not correlated with dissimilar measures, those intended to measure something different than the assessment of interest.[12,20–22] This would involve identifying tests measuring constructs intended to be measured by tasks for concurrent validity testing and tests measuring constructs that are not intended to be measured by the tasks for discriminate validity testing. Patients would complete both established tests and the tasks in the virtual environment and results would determine the correlation between assessments of similar and dissimilar constructs. Finally, further analyses involving detailed item/task analysis (i.e., factor analysis, differential item functioning) should be completed. See Figure 3.

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