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Ecologic validity in neuropsychological assessment: Prediction of wayfinding

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Abstract

This study compared the ability of clinical and ecologic simulation measures to predict performance on environment-specific criterion measures of wayfinding. Thirty-one unilateral stroke participants comprised the right and left hemisphere groups (16 patients with left sided and 15 patients with right sided strokes). Participants completed a battery of clinical tasks (e.g., traditional paper-and-pencil measures of visualization, mental rotation, visual memory and spatial orientation), ecologic simulations (e.g., slide route recall and visualization of a model town from differing perspectives) and environment specific criterion tasks (e.g., route recall and directional orientation). The groups were equivalent in age, sex, education, handedness, and weeks since stroke. Both ecologic simulation tasks were found to have fairly good internal consistency and 1 simulation task was significantly related to real world wayfinding. Of the clinical tasks, 1 visual memory test was correlated with a directional orientation criterion task, but none correlated with route navigation ability. Results are consistent with literature purporting the benefits of ecologic simulation tasks as predictors of real world functioning. (*JINS*, 2001, *7*, 675–682.)

Keywords: Ecologic validity, Wayfinding, Assessment, Visuospatial ability, Memory

INTRODUCTION

Wayfinding is the ability to navigate through familiar and novel environments in order to arrive at a destination. It is an ability that is crucial to independent functioning in society regardless of whether mobility is limited to walking or encompasses driving and the use of public transportation. Wayfinding is a highly complex skill that draws upon such basic abilities as learning (e.g., the acquisition of knowledge about a route), memory (e.g., recall of prior knowledge of a route), visual perception (e.g., detection of landmarks), spatial perception (e.g., determining the direction to take from a point along the route), map reading, and mental visualization (e.g., translating from map to environment; picturing the route in reverse).

Given its complexity, wayfinding is easily disrupted by brain damage. Following a brain injury, decisions regarding patients' ability to travel independently must be made. Currently available clinical and experimental tools that measure visualization, spatial orientation, mental rotation, and map reading have only an uncertain relationship to wayfinding (Cubic & Gouvier, 1997; Ekstrom et al., 1976; McGee, 1979; Passini, 1980; Sonnenfeld, 1985). While such measures may tap skills related to wayfinding, their ability to predict how well a person will navigate an actual route (i.e., ecologic validity) is largely undemonstrated (Passini, 1980).

The term ecologic validity has a variety of meanings. Within the assessment domain, ecologic validity can refer to the extent to which a test includes materials drawn from the everyday environment, the extent to which performance in a clinic setting resembles performance in a naturalistic setting, or the ability of a test to predict performance on some criterion of everyday functioning. Inclusion of materials drawn from everyday environments may increase the face validity of a test, but a test high in face validity does not necessarily contribute anything to clinical assessment (Sundberg, 1977). The ability of a test to predict to some everyday criterion is one aspect of a test's predictive validity. In this study, ecologic validity refers to the ability to generalize from a test to an everyday criterion.

There have been relatively few studies investigating the ecologic validity of tests of spatial skill. Sonnenfeld (1985) administered a battery of paper-and-pencil spatial tests to adults and children in Southeast Alaska and found that professional guides, fishing boat captains, and pilots were among

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the poorest performers. These results led to the conclusion that paper and pencil spatial performance was independent of true wayfinding ability. Kirasic (1988) found no significant relationship between elderly individuals' performance on psychometric tasks and their navigation ability. However, she found that performance on a photographic slide route simulation task correlated significantly with real-world spatial performance. Also using ecologic simulation, Walsh et al. (1981) found significant relationships between elderly individuals' knowledge of their own neighborhoods and performance on a model town perspective task. These studies suggest that tasks which simulate the spatial environment may possess greater ecologic validity than traditional psychometric measures, and indicates the need for further validation of ecologic simulation tasks.

In a recent paper in which they attempted to extract a universal taxonomy from the existing literature, Aguirre and D'Esposito (1999) described two elements fundamental to wayfinding, including route-based knowledge and a global, map-like understanding of the environment. Route learning is a linear process, with a sequential number of steps that travel from a starting point to a destination. This type of spatial representation requires the ability of an individual to maintain an awareness of his or her position in the environment. This is theoretically accomplished through recording of eye movements within their orbits and head movements upon the neck as a person perceives the location of an object in reference to the body. Thus, an individual keeps an *egocentric* position with respect to a landmark by *passing to the right* of the post office before turning left at the intersection. Aguirre and D'Esposito also describe a map-like representation of space occurring in *exocentric* space, in which the emphasis is upon the relationships of objects (including the navigator) within the environment (Taylor & Tversky, as cited in Aguirre & D'Esposito, 1999). Such representations involve the preservation of Euclidean (angle and distance) relationships which are independent of the navigator's position. These two elements appear in much of the wayfinding literature, according to Aguirre and D'Esposito, though with varying terms (e.g., route *vs*. configural, procedural *vs*. survey). Given the occurrence of these concepts in the wayfinding literature, studies which investigate the ability of ecologic simulation tasks to measure real world navigation ability should include criterion measures which represent both route-based and map-like spatial perception.

The present study investigates the ecologic validity of two environmental simulation tasks and several conventional clinical tasks measuring perceptual and memory abilities important in wayfinding. Unlike previous studies which relied solely upon patients' self-report of wayfinding performance, this study incorporates two criterion wayfinding tasks which require route-based knowledge (i.e., learned through navigation of an unfamiliar route) and Euclidean (angle) spatial representation. This study additionally extends the investigation of wayfinding to the stroke population. We expect to corroborate previous findings which suggest a lack of ecologic validity in clinical measures of spatial skill, and to support the use of empirically based ecologic simulation tasks to predict wayfinding.

METHODS

Research Participants

Participants were 16 left- and 15 right-hemisphere stroke patients from a rehabilitation facility affiliated with a major southeastern medical school. Medical records were screened to insure that participants met the following inclusion criteria: (1) being nonaphasic, (2) being able to adequately sustain attention for the duration of the session (approximately 2 hr), (3) being able to give informed consent, and (4) being able to adequately comprehend instructions.

T tests were used to compare right- and left-hemisphere groups on the following demographic variables: age, education, and weeks since stroke. There were no statistically significant differences detected on any of these variables (Table 1).

Analysis of variance confirmed that sex and handedness were roughly equivalent for the two groups. The participants tested in this study tended to be male, right-handed, and in their middle years. Most of the participants had some college education and were at least 2 years post stroke.

Measures

Conventional clinical tasks

Three conventional clinical measures were selected. The first two have been used in previous studies of wayfinding and the third is a common test of visuospatial learning and memory that would reasonably be expected to correlate with the ability to learn a criterion route. As these tests have

Table 1. Participant characteristics

Demographic variable	Right-hemisphere lesion	Left-hemisphere lesion
Age		
M	62.1	59.9
SD	11.2	16.5
Education		
M	14.4	14.9
SD	4.5	3.0
Weeks since stroke		
M	113.3	163.2
SD	157.4	158.1
Sex		
Male	$n = 9$ (60%)	$n = 14$ (88%)
Female	$n = 6$ (40%)	$n = 2$ (13%)
Handedness		
Right	$n = 14$ (93%)	$n = 14$ (88%)
Left	$n = 1$ (7%)	$n = 2$ (12%)

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been previously described, they will only be characterized briefly.

Surface Development Test (SDT; Ekstrom et al., 1976): This task measures the ability to imagine how a flat, two-dimensional drawing would look if folded to make a three-dimensional object. Reliability estimates in a normal sample for this task ranged from .90 to .92 (Ekstrom et al., 1976). The test was simplified to avoid a floor effect occurring in our stroke sample. Modifications included elimination of time constraints and the use of three-dimensional models of each object (in lieu of pictures) which could be held and manipulated. Participants studied the solid three-dimensional object and a corresponding unfolded two-dimensional drawing of the object. Participants mentally folded the flat image to form the object and determined which side on the flat paper drawing corresponded to a side of the solid object marked with an X. Scores were the number of objects for which the marked side was correctly identified.

Card Rotation Test (CRT; Ekstrom et al., 1976): This task measures the ability to mentally rotate objects in order to make a same/difference judgment. Ekstrom et al. (1976) reported reliability coefficients of .80 to .89 for this test. As before, we modified the test for use with a stroke sample by eliminating time limits and presenting stimuli one at a time (the original measure included a page of numerous stimuli). Participants viewed a key figure and determined whether subsequent figures were the same (though rotated) or different. Scores were the number of figures correctly identified as same or different.

Taylor Complex Figure–Tombaugh administration (TCF; Tombaugh et al., 1992): The TCF measures visuoconstruction ability and visual memory. Normative data are available over a 60-year age span, and reliability coefficients vary from .92 to .99 (Tombaugh et al., 1992). Participants viewed the figure for 30 s and then were given 2 min in which to draw the figure from memory. Four trials were administered in this manner. After a 15-min delay, a final recall trial was administered without additional exposure to the figure. Finally, participants copied the figure while viewing it. The Tombaugh et al. (1992) scoring procedure was followed, with scores based on the placement and presence or absence of various parts of the figure. As recommended by Tombaugh, recall trial scores were expressed as a percentage of the copy score to control for the effects of drawing difficulty.

Ecologic simulations of environmental tasks

Two simulations of environmental wayfinding were incorporated to assess topographic judgment and route learning.

Topographical Orientation Test (TOT): The TOT consists of color photographs of a model town, constructed on a 137 × 274 cm plywood base (Figure 1). The town includes a mock mountain, landscaping, central and side streets, street lamps, a railroad track, and scale models of vehicles and buildings. Participants viewed a key photograph of the town in which they looked straight down the main street with the mountain in the near left corner. In this photograph, a black post with an attached illuminated lightbulb appeared in one of six positions around the town. The six post positions were the four corners of the table and the midpoints of the right and left sides of the model. Participants were asked to imagine how the town would look if they stood directly behind the illuminated post and looked toward the center of town, then to select which of three photographs depicted the correct viewpoint. The key photograph and the three photographs showing different perspectives were in view for the duration of each trial and decision time was not limited. The initial practice trial differed only in that the illuminated post was positioned at the midpoint of the rear side of the model and participants had to make a choice from two photographs showing different views of the town. Consequently, practice and test trials did not overlap. The twelve test trials were presented in a fixed random order such that each of the six perspectives was represented twice in the key photographs.

Fig. 1. Item from the Topographical Orientation Test (actual stimuli are presented in color).

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Slide Route Recall (SRR): Participants viewed slides of a person standing at each of nine intersections along a mock route (Figure 2). The slides included five intersections with two-directional choices, and four intersections with three-directional choices. At each intersection, participants were given the number of directional choices while being shown a separate slide with the person looking in each of the possible directions. The next slide showed the person stepping in one of the directions and the final slide showed a closer view of the person walking in the chosen direction. Left, right, and straight decisions were equally represented (three each).

Intersections were viewed in a fixed random order and each was presented a single time for approximately 10 s. Between intersections, participants viewed a blank screen and were allowed to write any notes they thought would help them remember the turns. After all nine intersections had been viewed, participants were given two minutes during which they could study their notes. Notes were then removed and participants were shown each intersection and asked to point in the correct direction. In the first nine recall trials, intersections were presented in the same serial order in which they had been previously viewed. In a second set of nine trials, intersections were presented in a fixed random order, different from the order in which they were initially viewed. A block of serial and random recall trials were administered immediately after the 2-min study period and again after a 15-min delay.

Environment-specific criterion tasks

Criterion tasks involved the use of wayfinding skills in a specific environment.

Environmental Route Recall (ERR): Participants were pushed in a wheelchair along an unfamiliar route in a hospital. A wheelchair was used to minimize differences in exposure time to the route due to individual differences in ambulation speed. In addition, the wheelchair permitted participants to concentrate on the route and to avoid being variably distracted by their individual gait limitations. The route consisted of nine intersections with an equal number of right, straight, and left turns (three each). Three additional intersections were included for which no decision was required (i.e., they were not test items). Upon completion of the route, participants were taken back to the beginning via a novel path that did not overlap the previous route. Participants were then expected to travel the route from memory (Immediate Recall Trial). A delayed recall trial was administered after a 15-to-20-min delay.

Euclidean Task: During the learning phase of the ERR route, participants were shown, asked to point to, and name four landmarks in order: an elevator, a gift shop, a wall batik, and a portrait. Participants were then taken to a fixed location from which none of the landmarks were visible. Relative to this fixed point, the elevator lay 336°, the gift shop lay 349°, the batik lay 57°, and the portrait lay 41°away.

Fig. 2. Item from the Slide Route Recall Test (actual stimuli are presented in color).

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Participants were given a pointer (a protractor attached to a wooden board), with an arrow for pointing to the appropriate direction. Using the pointer, participants indicated the direction in which each landmark lay from the fixed point. The investigator recorded the degrees on the pointer for each landmark.

Procedure

Medical records were reviewed to identify potential participants based on our inclusion criteria. Participants meeting criteria for inclusion in the study were contacted and informed consent was obtained. Demographic data were gathered and each participant was tested individually. The sessions lasted about 2 hr for each participant. Tasks were administered to all participants in the following order: (1) Slide Route, Immediate Recall; (2) Taylor Figure Trials 1 to 4; (3) Surface Development Test; (4) Slide Route, Delayed Recall; (5) Taylor Figure Delay and Copy Trials; (6) Environmental Route, Immediate Recall; (7) Euclidean Task; (8) Card Rotation Test; (9) Topographical Orientation Test; (10) Environmental Route, Delayed Recall.

RESULTS

Three sets of statistical analyses were conducted to examine (1) the internal consistency (reliability) of the ecologic simulation tasks, (2) the ecologic validity of the clinical and ecologic simulation tasks, and (3) the differences in performance of right- and left-hemisphere participants on the clinical and ecologic simulation tasks.

Reliability

Internal consistency of the TOT and SRR were determined using Cronbach's alpha. Analysis revealed an alpha of .80 for the SRR and an alpha of .83 for the TOT. These results indicate fairly good internal consistency for both of the ecologic simulation tasks. We did not examine the reliability of the clinical tasks as these data were previously determined and reported by the test authors.

Ecologic Validity

Table 2 provides the performance means and standard deviations of both right- and left-hemisphere participants on

Table 2. Performance of right- and left-hemisphere groups on clinical, ecologic, and criterion measures

	Right hemisphere		Left hemisphere	
Measure	*M*	*SD*	*M*	*SD*
Clinical measures				
Surface Development Test	93.76	9.03	81.50	19.97
Card Rotation Test	82.50	11.92	85.47	14.59
Taylor Figure[a]				
Trial 1	35.41	17.14	35.28	12.37
Trial 2	51.42	14.98	53.67	18.22
Trial 3	60.75	16.28	66.15	19.26
Trial 4	64.57	21.04	71.00	21.36
Delay	64.07	23.87	72.50	20.23
Copy[b]	61.06	9.67	61.54	6.20
Ecologic simulation tasks				
Topographical Orientation Test	68.22	25.67	61.65	29.84
Slide route recall				
Immediate serial recall	66.68	19.89	70.39	20.86
Delayed serial recall	62.52	18.99	65.21	16.20
Immediate random recall	68.07	16.18	68.90	16.91
Delayed random recall	63.20	23.22	66.69	17.82
Environment-specific criterion measures				
Environmental Route recall				
Immediate recall	94.79	6.72	88.32	17.21
Delayed recall	97.39	5.88	93.33	12.67
Euclidean Task				
Degrees off from target	129.25	82.64	118.87	69.67

Note. Scores are expressed as percent correct. [a]Scores expressed as a percent of participant's copy trial score. [b]Expressed as raw score (maximum score = 69).

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Table 3. Pearson correlations between clinical and environment-specific criterion measures

	Environment-specific criterion measures		
Clinical measures	Environmental Route immediate route recall	Environmental Route delayed route recall	Euclidean Task total
Surface Development Test	.25	.18	−.22
Card Rotation Test	.17	.12	−.35
Taylor Figure			
Trial 1	−.09	.02	−.22
Trial 2	.16	.03	−.26
Trial 3	.14	.09	−.28
Trial 4	.21	.20	−.39*
Delay	.06	.11	−.42*
Copy	.05	.17	−.45*

*$p < .05$

each measure. These scores were compared to determine if performance on clinical or ecological tasks was similar to actual wayfinding ability. Consistently low and statistically nonsignificant correlations were found between performance on the clinical measures (SDT, CRT, and Taylor Figure) and the environmental route criterion task (see Table 3), suggesting these tasks are weak predictors of wayfinding. In contrast, the Taylor Figure (Acquisition Trial 4, Delayed Recall Trial, and Copy Trial) correlated with the Euclidean task at a statistically significant level. The latter correlations are negative because low scores on the Euclidean task represent more accurate direction estimates. Hence, the Taylor Figure appears to predict the ability to indicate the directions in which landmarks lie from a fixed point of reference.

Correlations between the Ecologic Simulations and Criterion measures are shown in Table 4. The Slide Route Recall task appeared to be a good predictor of wayfinding. The SRR Immediate Random Recall Trial was correlated significantly with the Immediate Recall Trial of the Environmental Route. All SRR trials correlated significantly with the Delayed Recall Trial of the Environmental Route. No significant correlations were obtained, however, with the Euclidean Task.

Right- and Left-Hemisphere Performance Differences

One-way analyses of variance (with Bonferroni corrections) were used to determine whether right and left hemisphere participants performed differently on the clinical and ecologic simulation tasks. There was a statistically significant difference on only one clinical measure, the Surface Development Test ($p < .05$). On this test, participants with right hemisphere lesions ($M = 93.7$ percent correct, $SD = 9.08$) actually outperformed those with left hemisphere lesions ($M = 81.4$ percent correct, $SD = 20.01$). Right- and left-hemisphere participants did not differ significantly on any of the ecologic simulations.

DISCUSSION

In her discussion of ecologic validity of neuropsychological assessment, Wilson (1993) suggested that traditional neuropsychological tests can be sensitive in discriminating brain injured participants from controls, but not particularly effective in predicting the kinds of everyday problems that result from the brain injuries. To accomplish the latter, we would need to create tests aimed specifically at predict-

Table 4. Pearson correlations between ecologic and environment-specific criterion measures

	Environment-specific criterion measures		
Ecologic measures	Environmental Route immediate route recall	Environmental Route delayed route recall	Euclidean Task total
Topographical Orientation Test	.13	.18	−.26
Slide Route recall			
Immediate serial recall	.26	.43*	−.22
Immediate random recall	.44*	.48**	−.06
Delayed serial recall	.32	.53**	−.20
Delayed random recall	.14	.39*	−.06

*$p < .05$; **$p < .01$.

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ing real-world ability, or in other words, tests which are ecologically valid.

The results of this investigation support the use of ecologic simulations over traditional clinical measures when attempting to predict an individual's ability to function in his or her everyday environment. Correlational analyses of the Clinical and Environment Specific Criterion tasks in this study suggest that while the measures may share spatial components, the Clinical tasks seem to measure at most only a small portion of the abilities required for wayfinding or directional orientation. Thus, the use of clinical measures of spatial ability to predict wayfinding is not supported by the current results. This conclusion is consistent with previous research demonstrating a lack of validity for clinical spatial measures in predicting real-world functioning (e.g., Ekstrom et al., 1976; McGee, 1979; Passini, 1980; Sonnenfeld, 1985).

The one exception to this was the significant relationship found between the Taylor Figure and the Euclidean Task. This relationship overall is not difficult to explain, as both tasks involve memory for spatial location. However, the correlation between the Taylor copy trial, which does not involve memory, and the Euclidean task is somewhat less clear. While perception of spatial location is still an aspect of successful performance on the copy trial, memory is no longer involved. As this was the highest correlation obtained from the Taylor Figure, it may be that perception of spatial location is the central component in this relationship. While the Surface Development and Card Rotation Tasks measure various aspects of spatial perception, they do not have any obvious spatial location component and for this reason may not have correlated with the environment-specific Euclidean Task.

The current results support our hypothesis that laboratory simulation of wayfinding is related to wayfinding in the real world, and are consistent with studies which suggest that ecologic simulations of environmental tasks are stronger predictors of wayfinding skill than traditional clinical measures (Kirasic, 1988; Long & Grissett, 1992; Walsh et al., 1981). Performance on the Slide Route Recall simulation task was found to significantly correlate with the real-world wayfinding ability necessary for the Environmental Route Recall criterion task. The tasks are similar in that they both involve skills such as route recall, landmark recognition, learning, memory, and visual and spatial perception. As previously described, subjects traversed the route while riding in a wheelchair in order to maintain a consistent length of exposure and attention to the route. This also prevented any problems with ambulation interfering with performance of the criterion task. Thus, this criterion task measures passive wayfinding ability. A subsequent study should attempt to replicate these results with a criterion measure requiring independent navigation of an unfamiliar route in order to document a relationship between the Slide Route Recall simulation task and active wayfinding as well.

The Topographical Orientation Test did not meet our expectations as an ecologically valid measure of wayfinding skill. It shares a unique landscape component with the SRR and Environment Specific Criterion tasks, but does not employ the visual memory and procedural learning components which may be fundamental to wayfinding. Additionally, while the Topographical Orientation Test requires perspective-taking, it does not require memory for the position of landmarks, a factor that may account for its failure to correlate significantly with the Euclidean Task (which requires the participant to remember the directional orientation of landmarks he or she had previously viewed). The Topographical Orientation Test may have predictive validity for real world spatial functions that were not measured by the criterion tasks included in this study. Consequently, we believe further research with this measure is warranted before concluding that it does not relate to any real world performance domains.

Interestingly, right and left hemisphere participants differed in their performance on only one measure employed in the current study. One would anticipate greater difficulty on visuospatial tasks for right-hemisphere stroke participants (Stringer, 1996), but in fact, on the Surface Development Test, the converse was true. This finding may reflect the inherent difficulty of the three-dimensional mental rotation task. Layman and Green (1988) noted that although patients with left-hemisphere lesions tend to perform better on simple tests of spatial skill, when faced with more complex spatial tasks, their performance may drop to a level equivalent to patients with right-hemisphere damage. In this case, the left-hemisphere group scored even lower on the spatial task than the right-hemisphere group. Another factor that may account for the lack of difference between stroke groups is the relatively long average length of time since stroke (greater than 2 years). Both the left and right hemisphere participants are likely to have recovered from and compensated for deficits in their spatial and wayfinding abilities.

In conclusion, we have reported data supporting the use of ecologic simulations of environmental wayfinding tasks. Such simulations have the potential to be reliable and valid measures of real-world functional abilities. They additionally have the advantages of laboratory or clinic-based administration and good potential for standardization and utilization across settings and patient populations. The current study reiterates the need for ecologically valid measures in neuropsychological assessment and generates optimism for further investigation of ecologic simulations as predictors of everyday cognitive abilities. A limitation of the current study was its relatively small sample size. Larger studies across a number of clinical diagnostic groups are needed before it can be definitively concluded that the ecologic simulations are superior to clinical measures in predicting real-world functioning.

While the slide route simulation shows promise, the current study is limited by the fact that we did not attempt to establish age or education norms for this task. Hence, it should not be used as a substitute for normed clinical tests even when prediction of everyday wayfinding ability is the assessment goal. However, with the establishment of the slide route simulation as a predictor of wayfinding, future investigations will incorporate normal control groups to further establish its psychometric properties. The current study suggests that ecologic simulations may be advantageous in predicting everyday performance. Future studies of the ecologic validity of both traditional clinical measures and everyday simulations are clearly justified.

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