Abstract Virtual Environments for Assessing Cognitive Abilities

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1. Abstract
We describe the design and pilot testing of abstract virtual environments (VE) for evaluating decision-making in neurologically impaired subjects. Instead of striving for visual realism, the VEs provide abstract representations of the necessary visual cues in a single screen setting. Pilot testing using this design strategy was conducted in 50 subjects: 28 had neurological impairments causing impaired decision-making (26 with focal brain lesions, 2 with Alzheimer's disease) and 22 were neurologically normal. Preliminary results are promising, suggesting that abstract VEs can distinguish decision-making impaired people where traditional neurological test batteries may not [1].

Figure 1. Go/No-Go Environment for testing driver decision-making. Botticelli's Venus is the lead vehicle.

2. Design
Our overall goal is to design and develop new tools for evaluating decision-making impairments in cognitively impaired populations and derive tools to help maintain and improve their cognitive functions. Development of a cost-effective and easy-to-maintain system required visual representations that communicate spatial orientation and optical flow in the limited field of view of a standard PC desktop monitor. This approach draws from perceptual psychology, computer graphics, art, and human factors studies of visual cognition. We deviated from traditional simulation approaches, focusing on our assessment needs without assuming visual realism was necessary. The VE was designed to provide sufficient pictorial and motion cues relevant for perceiving spatial relationships of objects and user orientation [2, 3]. Similar to high-fidelity driving simulators and in-vehicle navigational systems, it utilizes motion parallax, optical flow caused by moving objects and the observer, shading, texture gradients, relative size, perspective, occlusion, convergence of parallel lines, and position of objects relative to the horizon. By deviating from a realistic VE design we have an open design space for creative exploration of scenario design and development. Scenario design is guided by cognitive neuroscience (to localize performance errors in specific cognitive domains that are crucial to the real-world task being simulated). We successfully implemented this approach in pilot studies aimed at testing critical Go/No-Go decisions by subjects with cognitive impairments caused by focal cerebral lesions.

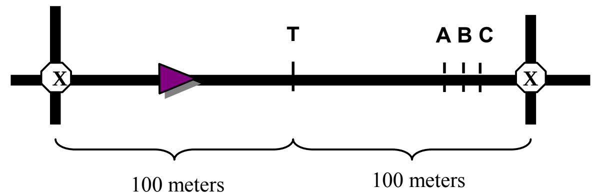

Figure 2. At point T, gate-closing trigger point A (easy), B (medium), or C (difficult) is computed, based on current speed, deceleration limit, and other parameters.

3. Scenario
In the Go/No-Go scenario, each subject drove through a series of intersections (marked by 'X's in the schematic representation in Figure 2) spaced 200 meters apart. Each intersection had gates that opened and closed. When the subject reaches point T, 100 meters before an intersection, a green "Go" or red "Stop" signal appeared at the bottom of the display and a gate-closing trigger point (A, B, or C) was computed based on a deceleration constant, gate closure animation parameters, subject speed, and amount of time allotted to the subject to make a decision. Gates began closing the moment the subject reached the gate closing trigger point. The allowed decision times (braking distances) were "easy", "medium", or "difficult" (shortest possible braking distance). Approximately 1/3 of the gates were represented at each difficulty level and difficulty levels were randomized so as to be unpredictable to the subject.

4. Results
The results of the pilot tests using sophisticated, yet surrealistic ('low fidelity") scenarios are promising and highly relevant to the simulator fidelity question: "how low can you go?" Significant differences in errors (i.e., crashes into closed gates and failure to go at open gates) and reaction time measures ($p<0.05$, all cases) were found between brain-damaged and control subjects. Between group differences identified using the Go/No-Go task were not consistently demonstrated on standard neuropsychological tests. Moreover, the finding of a shallower learning curve across Go/No-Go trials in brain-damaged subjects suggested a failure of response selection criteria based on prior experience, as previously reported in brain-damaged individuals with decision-making impairments on a gambling-related task [1].

5. References
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