Comprehensive Assessment for Executive Dysfunction

Vito Scutari[1]; Jordan Tewell, PhD[2]; Nicole Cruse, PhD[1,2]
[1]King School, [2]Sacred Heart University

Abstract

Each year, over one million people in the United States suffer from traumatic brain injury (TBI), with 230,000 requiring hospitalization and 50,000 ultimately dying. Of those hospitalized, 34% are discharged with TBI-related disabilities, contributing to the estimated 5.3 million Americans living with TBI-induced impairments today. These impairments severely impact patients' ability to perform everyday tasks. Additionally, TBI can affect anyone, from an average person to a professional athlete. Furthermore, traditional assessment methods for executive dysfunction are not only costly and time-consuming but also prone to human error due to their paper-and-pencil or verbal nature, limiting their effectiveness in frequent evaluations. This paper presents the Comprehensive Assessment for Executive Dysfunction (CAED), a mobile, tablet-based, gamified tool designed to overcome these challenges. By integrating gaming elements with clinical evaluation, CAED offers a more accurate, efficient, and patient-friendly approach to assessing executive dysfunction in TBI patients. CAED features realistic game scenarios that replicate daily activities. Player behavior, timing, and decisions within these scenarios are tracked and when analyzed, will provide insights into patients' cognitive function. Significant progress has already been made, specifically in its software architecture and visual design including basic systems and concept art. CAED has the potential to revolutionize neurological assessment and rehabilitation, offering a novel, technology-driven solution to improve care for individuals with TBI.

```
public static ScenesManager Instance = null;

public GameObject player;
public GameObject[] doorArray;
CameraController cameraController;
GameObject mainCamera;

public int currentDoorNumber;
private Vector3 DoorOffset = new Vector3(1, 0, 0);

private void Awake()
{
    if (Instance == null)
    {
        DontDestroyOnLoad(gameObject);
        Instance = this;
    }
    else if (Instance != null)
    {
        Destroy(gameObject);
    }

    if (player == null)
    {
        player = GameObject.FindGameObjectWithTag("Player");
    }
    if (doorArray.Length == 0)
    {
        doorArray = GameObject.FindGameObjectsWithTag("Door");
    }
}
public void LoadScene(int passedDoorNumber, string targetScene)
{
    currentDoorNumber = passedDoorNumber;
    SceneManager.LoadScene(targetScene);
}

void OnLevelWasLoaded()
{
    player = GameObject.FindGameObjectWithTag("Player");
    doorArray = GameObject.FindGameObjectsWithTag("Door");
    mainCamera = GameObject.FindGameObjectWithTag("MainCamera");
    cameraController = mainCamera.GetComponent<CameraController>();

    for (int i = 0; i < doorArray.Length; i++)
    {
        if (doorArray[i].GetComponent<InteractableSwitchWorld>().doorNumber == currentDoorNumber)
        {
            player.transform.position = doorArray[i].transform.position + DoorOffset;
            cameraController.SwitchedScene();
```

Figure 1. ScenesManager script used for Scene / Door System. This image shows the ScenesManager script that was used to implement the Scene Switching / Doors system within CAED.

Results

- **Player Movement System**
  - Utilizes an On-Screen joystick, designed to be used on a touch-screen tablet
  - However, Keyboard functionality was implemented to allow for on-the-fly testing during development.
- **Camera System**
  - Dual-camera system to allow for Dialogue Interactions
    - Default Camera - 3rd Person Perspective above and behind the player.
    - Dialogue Camera – On-the-shoulder view to allow for better view of NPC (Concept Art Shown in Figure 3).
- **Interaction System**
  - Dialogue Interactions (using YarnSpinner) allowing the player to talk with NPCs in the scene
  - Item interaction that works with with the Inventory system to allow the player to pickup and use certain items
- **To-Do List / Quest System**
  - Unique Quest and Step objects that work with CAED's UI to inform the player of how to proceed
- **Inventory System**
- **Scene-Switching system** was created to allow for multi-scene scenarios (Figure 1)
- Concept art of the game was drawn to be used as a model.
- CAED's scenarios were outlined in a document:
- A map of the town was created with all the necessary locations.
- Finished scenes within Unity:
  - Town, Sandwich Shop, Bookstore, Pizza Shop, Laundromat, Hibachi, Cafe, Bank, Gym, and Office
- 3D models and 2D textures of Objects, Player, and NPCs created

Future Expectations:

- Enhance the evaluation and diagnosis of TBI by offering detailed insights into patients':
  - Decision-Making Processes
  - Path Navigation
  - Time Management
  - Task Completion Efficacy
  - Behavioral Patterns
- These metrics, along with responses from the initial screening questionnaire, will be auto-compiled into a report for clinicians. This is expected to lead to:
  - Improved Diagnostic Precision
  - Enhanced Patient Engagement
  - Efficiency in Clinical Settings

Figures

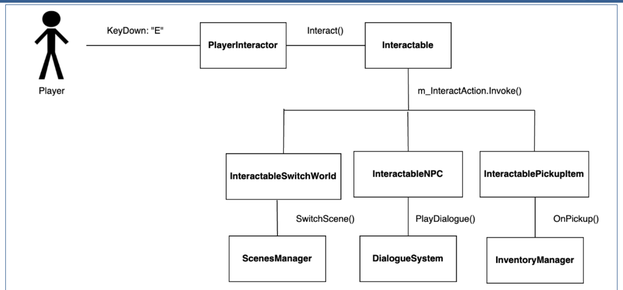

Figure 2. Interaction System Flowchart. This flowchart illustrates the interaction system in a game, where the player triggers interactions by pressing the "E" key. The PlayerInteractor component detects this input and calls the Interact() function on an object classified as Interactable. Interactables are subclassed into three types: InteractableSwitchWorld, InteractableNPC, and InteractablePickupItem. Each subclass triggers specific actions: switching scenes via the ScenesManager, playing dialogues through the DialogueSystem, or picking up items using the InventoryManager. The interactions are initiated by invoking the m_InteractAction function, which links player input to game responses.

Figure 3. Concept art of a dialogue interaction with an NPC. Concept art showcasing a dialogue interaction. The scene depicts the player engaging with an NPC, a worker at "Sammy's Sandwiches," inside a sandwich shop which is a part of one of the scenarios within CAED. The worker, dressed in a red uniform, greets the player with the message, "Hi, Welcome to Sammy's Sandwiches. How can I help you today?" The conversation is presented in a classic RPG-style dialogue box at the bottom of the screen.

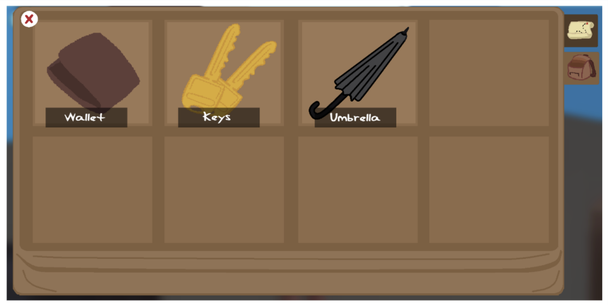

Figure 4. Concept art of Player Inventory. Concept art of the Player Inventory interface for the app, displaying three items: a wallet, keys, and an umbrella. The inventory is organized in a grid layout with labeled slots, and quick-access icons for the map and inventory are visible on the right, along with an X button that allows the user to exit the inventory.

Figure 5. Concept art of gameplay, including the HUD. Concept art for the app's gameplay interface, featuring a player character navigating a park environment. The HUD includes a time display, a To-Do List, and a visible currency counter. UI elements include directional controls, a pause/help button, and quick-access icons for the map and inventory on the right.

Contact Information

Vito Scutari vitoscutari1407@gmail.com +1 (469) 880 8361

Discussions & Conclusions

The development of CAED marks a promising advancement in the relationship between technology and healthcare, specifically in neurological rehabilitation. CAED's design, which gamifies clinical assessment and rehabilitation, aims to provide a novel, user-friendly tool for evaluating executive functions in individuals with TBI. The project's approach, which draws from existing brain-activity-related games and popular traditional games, ensures that the tool is both engaging and effective in its purpose. CAED's core gameplay, which mimics everyday tasks through a series of structured scenarios, allows for the practical assessment of executive dysfunction in a controlled and safe virtual environment. The use of a to-do list, dynamic NPC interactions, and scene-switching mechanics adds realism and complexity, making the game closer to the real-world challenges faced by TBI patients. This approach not only enhances the assessment process but also improves user engagement, which is crucial for obtaining accurate and meaningful results. The project has already successfully implemented key systems, including a camera system that adjusts perspectives during interactions. This feature, along with the careful design of the tool's environments and tasks, ensures that CAED is intuitive and accessible to users who may have cognitive impairments. Additionally, the preparation and literature review conducted prior to development has informed the design, contributing to the creation of a tool that is grounded in both clinical and gaming best practices. However, while the initial development and testing phases have been successful, there is still progress to be made. More scenarios need to be created before the tool can be integrated into clinical settings. Moreover, extensive testing with TBI patients is required to validate CAED's effectiveness and reliability as a diagnostic tool.

References

1. International Brain Injury Association (n.d.). Brain Injury Facts. Retrieved 2024, Aug 27. https://www.internationalbrain.org/resources/brain-injury-facts
2. Pietrzak, E., Pullman, S., and McGuire, A. (2014). Using virtual reality and videogames for traumatic brain injury rehabilitation: A structured literature review. Games for Health, 3(4). 202-214. doi: 10.1089/g4h.2014.0013
3. Miller, G. F., DePadilla, L., and Xu, L. (2021). Costs of non-fatal traumatic brain injury in the United States, 2016. Med Care, 59(5). 1-10. doi: 10.1097/MLR..0000000000001511.
4. Tong, A., Chignell, M., and Sieminowski, T. (2015). Case Study: A serious game for neurorehabilitation assessment. Procedia Computer Science, 69. 125-131 doi: 10.1016/j.procs.2015.10.013
5. Sagary R, Malim NHAH, Abdullah NL, Mohamad WNAW, and Ahmad AL (2023). Impact of mobile games-aided neurorehabilitation: A systematic literature review. Malays J Med Sci, 30(6). 29-44. Doi: 10.21315/mjms2023.30.6.4
6. Webb, S. S., Jespersen, A., Chiu, E. G., Payne, F., Basting, R., Duta, M. D., and Demeyere, E. (2022). The Oxford digital multiple errands test (OxMET): Validation of a simplified computer tablet based multiple errands test. Routledge,32(6). 1007-1032. doi: 10.1080/09602011.2020.1862679
7. Yarn Spinner Developers (n.d.). Yarn spinner documentation. Retrieved 2024, Aug 23. https://docs.yarnspinner.dev/