CogWorldTravel: Design of a Game-Based Cognitive Screening Instrument

Fernanda T. Oliveira[1,2(✉)], Brandon W. Tong[1,3], Jaime A. Garcia[1,2], and Valerie C. Gay[2]

[1] University of Technology Sydney (UTS) Games Studio, Sydney, Australia
Fernanda.TavaresVasconcelosOliveira@student.uts.edu.au
[2] Faculty of Engineering and IT, UTS, Sydney, Australia
[3] Faculty of Health, UTS, Sydney, Australia

Abstract. Cognitive Screening Instruments are helpful in the early detection of cognitive changes and possible underlying dementia. These instruments test all major cognitive domains of an individual. Serious games have been investigated as an alternative approach for cognitive assessment because of their ability to motivate. Previous work mostly focused on finding out whether it is feasible to use a serious game for such purpose. We decided to investigate further how a serious game can be engaging and fun while prioritizing the cognitive assessment. In this paper, we describe the design, development, and evaluation of CogWorldTravel, a serious game that has the potential to be used for cognitive screening as it measures at least one aspect of each cognitive domain. CogWorldTravel features six game tasks that involve recognition memory, attention, working memory, language, immediate memory span, processing speed, inhibition, recognition of emotions, visuoconstructional, perceptual-motor, and planning abilities. The serious game also accommodates age-related changes and considers the gameplay preferences of older adults.

Keywords: Serious Games · Games for health · Cognitive screening · Older adults · Dementia

1 Introduction

Older adults are at a greater risk for the onset of dementia, which is characterized by impaired cognition that represents a decline from a previously attained level of functioning [1]. Undiagnosed dementia has severe and expensive consequences for individuals, their families, and society [2]. Cognitive Screening Instruments (CSIs) are used to assist in the assessment of dementia [3]. Although these tools are not diagnostic, they are useful in the early detection of cognitive changes and possible underlying dementia. The detection of cognitive changes is the first step toward accurate diagnosis. Ideally, these instruments should test all major cognitive domains of an individual [4], namely complex attention, executive function, learning and memory, language, perceptual-motor, and social cognition [1].

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There are several well-researched CSIs currently used to detect dementia. However, these instruments do have limitations. A relevant barrier to the proper use of such instruments is the time required for administration in clinical settings. It is well known that the environment where the test is undertaken may affect performance [3]. Especially for pen-and-paper-based tests, results may vary across examiners [4]. In addition, most tests are dependent on language, and scores must be validated independently in each language as they may vary when tests are translated. Similarly, educational and cultural biases are evident in many instruments [3]. The development of CSIs that are less sensitive to language, education, and culture is still highly encouraged [5].

Serious games are regarded as games that entertain players while accomplishing another primary purpose. The rationale for using game technology for such serious purposes is its ability to motivate [6]. Serious games have been beneficial in delivering several personalized healthcare solutions for older people [7]. In the last years, considerable attention has been focused on investigating the use of serious games for cognitive screening [8]. Serious games have advantages in overcoming the limitations of traditional CSIs, particularly when compared to pen-and-paper-based tests. Game-based tests ease the administration process. As they can be self-administered, they can be used in clinical settings and remotely. Older adults can play the serious game at home while useful data is being collected and can be shared with a healthcare professional. As total and partial time-based measures for diverse tasks can be collected and scores can be calculated, recorded, and tracked automatically over time, it reduces the risk of biased administration.

Previous research in this field mostly focused on assessing the feasibility of using games for cognitive screening [8]. The common approaches involved collecting data through existing games or developing bespoke games that replicate the mechanics of cognitive tests. From existing games, Gielis *et al.* explored the Microsoft Solitaire Collection with an additional toolbox that captures digital biomarkers such as time spent thinking before making a move and error during gameplay that may be indicative of planning, executive functioning, or attention decline [9]. Intarasirisawat *et al.* developed their own version of Tetris, Fruit Ninja, and Candy Crush Saga to be able to collect in-game data through tap and swipe interaction patterns [10]. Siraly *et al.* analyzed time to complete the classical 'Find the pairs' memory game [11]. Bonnechere *et al.* investigated using a suite of eight brain training mini-games from the Peak mobile app [12]. Although these commercial or well-known games are fun and engaging, and studies found that a correlation between game performance and cognitive health exists, games that were not built for such purpose do not satisfy the requirements of CSIs, specifically the need to sample all cognitive domains. In addition, commercial games, in general, do not necessarily target older adults, and they have age-related changes that ideally must be addressed when designing for them.

On the other hand, other studies developed bespoke games for cognitive screening. Those bespoke games either simulate activities of daily living or try to replicate activities from traditional tests. Eraslan Boz *et al.* proposed a virtual supermarket [13], Vallejo *et al.* [14] and Manera *et al.* [15] developed virtual cooking tasks to evaluate participant performance in the simulated activities. Hagler *et al.* created the Scavenger Hunt, which is based on the pen-and-paper Trail Making Test that measures cognitive functioning

[16]. Tong *et al.* proposed The Whack-a-Mole, which is inspired by the classical Go/No-Go Discrimination Task that measures inhibition [17]. Valladares *et al.* presented the Panoramix suite that is based on multiple cognitive tests, including the California Verbal Test, the Pyramids, and Palm-trees test, the Corsi Cubes test, and the Pursuit Rotor Task test [18]. Although bespoke games offer the opportunity to explore different aspects of cognition and provide a measure of all cognitive domains, previous works did not exactly focus on this.

The use of commercial and bespoke games to assess cognitive functioning has demonstrated promising results; however, investigating design approaches to develop an ideal game-based CSI is still an open challenge. An ideal game-based CSI must comply with the criteria for such an instrument [4], satisfy age-related changes of older adults [19], and be engaging and fun for most older adults. In this context, we decided to investigate further how a serious game can be engaging and entertaining while prioritizing cognitive assessment. This paper describes the design, development, and evaluation of CogWorldTravel, a serious game for cognitive screening that measures at least one aspect of each major cognitive domain. The game features six game tasks that involve recognition memory, attention, working memory, language, immediate memory span, processing speed, inhibition, recognition of emotions, visuoconstructional, perceptual-motor and planning abilities.

The following section presents the methodology of this work. In Sect. 3, CogWorldTravel is unfolded. The evaluation of CogWorldTravel is described in Sect. 4. Discussions and conclusions can be found in Sect. 5 and Sect. 6, respectively.

2 Methodology

This section describes the methodology followed to design, develop, and evaluate CogWorldTravel. The aged cohort is very diverse, and there was no expectation of designing a 'one-size-fits-all' game. However, as traveling is an experience enjoyed by most people, we started by choosing this topic to revolve the game story around it.

We reviewed the literature, searching for design recommendations for older adults as they have a higher chance of presenting difficulties in hearing, vision, cognition, or mobility [19]. In addition, we reviewed classical CSIs currently used in clinical practices to understand the items contained in those tests and which cognitive aspects they measure. We also considered the features that an ideal CSI must include, as enunciated in the Report of the Committee on Research of the American Neuropsychiatric Association [4]. We reviewed the cognitive domains defined in the latest version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), namely complex attention, executive function, learning and memory, language, perceptual-motor, and social cognition. We observed working definitions of each domain, examples of symptoms or observations regarding impairments in everyday activities, and examples of assessments.

After we conducted the literature review and understood the context of the problem, we defined the requirements that would drive the design of the game-based CSI for older adults to ensure the game accommodates age-related changes [20], includes all major cognitive domains [1], and can be administered remotely. The requirements were defined as follows:

The game-based CSI should:

1. avoid small font sizes.
2. use contrasting colors.
3. require simple inputs from the user during gameplay.
4. include slow-paced tasks with a clear objective explained through a tutorial.
5. measure one aspect of complex attention at a minimum.
6. measure one aspect of executive function at a minimum.
7. measure one aspect of learning and memory at a minimum.
8. measure one aspect of language at a minimum.
9. measure one aspect of perceptual-motor at a minimum.
10. measure one aspect of social cognition at a minimum.
11. not rely on literacy level.
12. not rely on language skills unless when assessing it.
13. be playable by older adults in a home environment without the supervision of a trained professional.
14. enable older adults to share their results with a healthcare professional.

The next stage consisted of designing a solution to meet the defined requirements as far as possible. Game tasks were brainstormed and discussed between the authors, and an initial design was agreed upon.

We developed a computer version of the serious game using Unity due to its versatility for developing game prototypes. The game is available at the following link: https://urfriendxd.itch.io/cogworldtravel. The data collected during gameplay are stored in a CSV file and can be shared with a healthcare professional. The Unity built-in recorder package supported the development of tutorials. The computer version of the game would allow us to ask participants to play the game remotely while having a Zoom session with them in case we needed to comply with social distancing restrictions due to COVID-19 throughout the study.

The evaluation of CogWorldTravel consisted of two phases. In the first phase, interviews with five experts in the assessment of dementia were conducted individually. Each mini-game was demonstrated, the rationale was explained, and they were asked whether they believed the mini-game had the potential to provide a measure of the cognitive aspects that it intended [21]. In the second phase, we interviewed six older adults aged 60+. They were asked to play the serious game. Then, we asked the following: (1) if they were able to understand the task from the tutorial, (2) if they had any issues playing the game, (3) if they enjoyed playing the game, and (4) how they would rate the game in terms of difficulty.

3 CogWorldTravel

CogWorldTravel is a serious game that features six game tasks for the assessment of all major cognitive domains. This section describes the structure of each game task, including game elements as defined by Fullerton *et al.* in [22]. Although anyone can play CogWorldTravel, the targeted players are older adults as they are the ones at a greater risk of developing dementia. As the name implies, travelling is the game's theme, and the game tasks are inserted in this context. All game tasks have their foundations in previous research and were refined during the iterative design process that involved stakeholders.

3.1 Familiar Faces

- Story: The player arrives at the airport and finds out that their luggage is gone. They will work closely with security to identify who has their luggage by mistake (see Fig. 1).
- Objective: The goal of the player is to select as many faces as they can without selecting the same face twice.
- Procedure: Sets of six to ten faces will be displayed at a time. The player uses the mouse to select one face. After the face is selected, the whole set disappears, and a new set is displayed, re-ordered, including faces already chosen by the player at any time and at least one face that has never been selected. The same process repeats until the player selects the same face for the second time.
- Rules: The players click on the faces to help security in identifying people, but they cannot click on the same person twice as it would be an awkward situation.
- Conflict: This is a cognitive challenge, and the player may be limited by their own ability to track the faces while performing the task. They need to resolve how to hold up to 50 different faces in memory to be able to go through as many as they can.
- Outcome: The game ends when the player selects someone for the second time, and the data collected during gameplay is the number of faces that were selected before losing the game. It is expected that the number of faces achieved is an indication of recognition memory, sustained attention, and working memory performance, as these are cognitive abilities required in this task and represent elements of the major cognitive domains of learning and memory, complex attention, and executive function, respectively. This game satisfies requirements 5, 6, and 7.
- Rationale: This task was inspired by the Warrington Recognition Memory Test for faces [23], which assesses deficits in recognition memory, which is an important expression of episodic memory. The decline of episodic memory is a hallmark of cognitive dysfunction associated with dementia. In the original test, which has been previously considered to have the ability to detect dementia [24, 25], 50 faces are presented to the participant, and later they are challenged with a pair of faces to identify which one they had seen before.

3.2 Padlock Combination

- Story: After the player retrieves the luggage, they realize they forgot the padlock combination to open it, and they will need to guess (see Fig. 1).
- Objective: The player should form as many words of three or four letters as they can with the given set of four letters from the padlock.
- Procedure: The padlock contains a set of four letters. Using the mouse, the player selects each letter to use it to form words. The player can unselect a letter by clicking again on it or clicking the clear button to delete all letters in one go. Once one word is formed, they click on the submit button. If the word is accepted, a green light appears. If the word exists but has already been submitted, yellow light is displayed. If the letters selected do not form an existing word, a red light is displayed. Each set of letters has a defined number of words that need to be formed. If the player completes it, a new one is given until the two-minute timer is over.

- Rules: The words formed by the player must be composed of three or fours letters and cannot include names. Each letter can only be used once for each word. The combination formed only can be submitted if it is an existing word. The same word cannot be submitted twice.
- Conflict: This task is timed, and the number of words that the player can generate is limited by the time provided to complete the task.
- Outcome: The game ends when the time ends, and the data collected during gameplay is the number of words that were successfully submitted. It is expected that the number of words achieved is an indication of language and working memory performance as these are cognitive abilities required in this task and represent elements of the major cognitive domains of language and executive function, respectively. This game satisfies requirements 6 and 8.
- Rationale: Although it is different due to the elimination of the human component in the administration of the game-based test, the task is inspired by the assessment of language skills of the Montreal Cognitive Assessment (MoCA) [26], where the participant is asked to say as many words as they can starting with a given letter, name low-familiarity animals, and repeat a sentence. In this task, the player uses an element of language to recall words that can be formed with the letters and needs to hold the words already submitted in memory.

3.3 The Metro

- Story: After all luggage-related issues are resolved, it is finally time to enjoy the trip. The player can visit tourist spots around the city using the metro system. A local expert will show those spots on the map (see Fig. 1).
- Objective: Memorize and repeat the longest sequence of highlighted stations as possible.
- Procedure: The player will see a metro map. The stations on the map will be highlighted. The player needs to repeat the sequence highlighted by using the mouse to click on the stations in the same order that they were shown. The game starts with a sequence of three stations. The player has two trials to attempt to repeat a three-stations-long sequence. If at least one sequence is correctly repeated, the next sequence displayed will be incremented by one station. The process repeats until the player cannot repeat any of the two trials of a given length.
- Rules: Two different sequences of the same number of stations will be displayed. One station is added to the number of stations highlighted if the player successfully repeats at least one of the sequences. The trial ends when the player selects the expected number of stations, even if it is not correct.
- Conflict: This is a cognitive challenge, and the player may be limited by their own immediate memory span ability.
- Outcome: The game ends when the player is not able to repeat at least one of the trials for a given length. The data collected during gameplay is the maximum length achieved and the total number of correct repetitions. It is expected that these data collected will provide an indication of immediate memory span, which is an element of the learning and memory domain. This game satisfies requirements 7.

– Rationale: This task was inspired by the Corsi Blocks Test, which requires memorization of relative positions in space in a temporal order. The test consists of nine square blocks positioned on a board [27]. The examiner taps the blocks starting with sequences of two cubes. The participant has to reproduce the sequence by tapping the blocks in the same order. The test has been considered the single most important nonverbal task in cognitive assessment [28].

3.4 Native Fauna

– Story: One of the places visited by the player is the beach. The player is instructed to take photos of the native wildlife at the beach (see Fig. 1).
– Objective: The player should take photos of flamingos that appear on the screen as quickly as possible and avoid photographing the coconuts.
– Procedure: The player goes around the screen with the mouse, which replicates the view from the lenses of a photographic camera. They should stay alert to the appearance of the flamingos on the screen. They must click on the flamingos as quickly as possible. Coconuts will also randomly appear as distractions, and the player must avoid taking photos of them.
– Rules: The player must click on the target (Flamingos) and avoid the distractions (coconuts). A green light is displayed when a target is hit, and red light is displayed when a distraction is hit.
– Conflict: Coconuts are included to test inhibition. The player must stop themselves from responding when coconuts are seen.
– Outcome: The player will be exposed to a defined number of targets and distractions, and the data collected during gameplay include reaction time, correct photos taken (target), wrong photos taken (distraction), and missed targets. It is expected that the data collected will provide a measure of processing speed, inhibition, and sustained attention, which are elements of complex attention and executive function. This game satisfies requirements 5 and 6.
– Rationale: The task replicates the same mechanics of the letter A item from the MoCA [26], where the participant listens to a list of letters and claps hands every time they listen to the letter A. One advantage of the game over the classical test is the ability to provide time-based measures, which enables the measurement of reaction time. Reaction time is acknowledged as an important parameter of cognitive efficiency [29]. The addition of the distraction element in the game also provides a measure of inhibition as it tests the ability to stop yourself from responding to a stimulus. This is measured in the go/no-go [30] cognitive test.

3.5 Messaging Home

– Story: The player has a little break from the trip to check in on their family back home. They talk to a family member through a messaging app (see Fig. 1).
– Objective: The goal of the player in this game task is to select the correct sticker that will support the conversation.

- Procedure: A text conversation between the player and their daughter is displayed. In the conversation, feelings are mentioned. The player is asked to choose a sticker to support the feeling mentioned in the conversation from a set of six faces expressing the basic emotions: happy, sad, angry, surprised, disgusted, and scared. All six emotions will be mentioned once, but the player is not aware of this beforehand.
- Rules: The player must choose one face at a time to support the feeling in the conversation. There are six faces and six trials. Once a face is selected, the conversation continues.
- Conflict: The correct face is shown among five other faces, and the player is limited by their ability to recognize emotions in faces when selecting it.
- Outcome: There is no losing criteria or time limit. The player can take their time to select the most appropriate face. The data collected during gameplay is the total number of correct faces of six trials. It is expected that it will provide a measure of recognition of emotions, which is one aspect of social cognition. This game satisfies requirement 10.
- Rationale: Social cognitive deficits are commonly seen in people with dementia [31], even though this domain is often overlooked in classical and game-based instruments. The game task is very similar to the Emotion Recognition Task [32], with the difference that the emotions are inserted in the context of the trip rather than simply showing a word.

3.6 Time to Pack

- Story: At the end of the trip, the player must pack their luggage before flying home (See Fig. 1).
- Objective: The player should place tetrominoes-shaped items inside suitcases and complete as many suitcases as they can.
- Procedure: The tetrominoes-shaped items will be displayed to the player alongside a suitcase. The player needs to organize the items inside the suitcase, and they may need to rotate the items. Items are rotated 90 degrees clockwise by selecting them and clicking the right mouse button, or pressing the space bar. Items must be dragged and dropped inside the suitcases. Once all items are placed inside the suitcase, it closes, and a new empty suitcase and new items are provided. This repeats until the two-minute timer is over.
- Rules: Players can drag and drop items inside and outside the suitcases. The player can change the position of the items as many times as they wish after placing them inside the suitcase. If the timer is over, the player cannot continue with the suitcase they were packing at that moment.
- Conflict: This is a cognitive challenge where items need to fit inside the suitcase perfectly. No spaces can be left. The game is limited by time.
- Outcome: The game ends when the time ends, and the data collected during gameplay is the number of suitcases completed in the given time. It is expected that it will provide a measure of visuoconstructional, perceptual-motor, and planning abilities, which are aspects of perceptual-motor and executive function. This game satisfies requirements 6 and 9.

– Rationale: This task was inspired by the Tetris puzzle game, which has been considered to involve rapid visual-spatial problem-solving and motor coordination skills [33].

Fig. 1. CogWorldTravel.

4 The Evaluation of CogWorldTravel

In the first phase of the evaluation of CogWorldTravel, we interviewed five experts in the assessment of dementia. In general, the experts liked the concept of the game and assessed that *Familiar Faces* could provide a measure of recognition memory, attention, and working memory. *Padlock Combination* could provide a measure of executive function and a component of language. *The Metro* could provide a measure of immediate memory span, visual scanning, and visual awareness. *Native Fauna* could provide a measure of processing speed, sustained attention, and inhibition. *Messaging Home* could provide a measure of recognition of emotions. Finally, *Time to Pack* could measure perceptual-motor, attention, planning, and manipulation of visuospatial information. Further details on the evaluation of CogWorldTravel through the interviews with experts are described in [21].

In the second phase of the evaluation process, we tested the game with six participants, referred to as P1, P2, P3, P4, P5, and P6. The eligibility criteria considered during the recruitment included being 60 years old or older, speaking English fluently, and being able to consent. In total, four female and two male participants joined the study. Five understood the goal of *Familiar Faces,* and no significant problems were reported. P3 said she had an issue relating the game's story with the goal of the task but still knew what she needed to do. P5 said he was confused with the thumbs-up that appeared each time the player chose a different face. He said that it seems like you found the person who has your suitcase but actually, it means you are doing well in the game and not choosing the same person. They were able to select 25, 1, 27, 4, 6, and 21 faces, respectively, before making a mistake.

In *Padlock Combination*, two participants missed that the words could be formed by three or four letters. P3 said that because of the analogy with a padlock, she was expecting to see numbers instead of letters. P4 suggested that a hint could be provided when the player cannot find a new word to avoid frustration. The number of words formed was 12, 6, 5, 6, 12, and 4, respectively.

In *The Metro*, because the game starts with a sequence of three stations being highlighted, they were expecting that the following sequence to be displayed also would be of three stations. They suggested communicating that the length of the sequence would increase. The maximum length achieved was 3, 4, 4, 5, 3, and 4, respectively.

Two of the participants found *Native Fauna* very fast. The coconut included as distractions did not make a difference in the game, as the participants have rarely hit it. P5 suggested that the distraction should be more similar to the target to increase the difficulty. P4 mentioned that the length of the activity could be challenging for their age group as they were expected to hit 50 targets. The average reaction time was between 1.60 and 1.90 s for all participants.

No major issues were reported for *Messaging Home*. Only P4 mentioned that she would prefer that the images were not monochromatic. The participants correctly selected 4, 3, 5, 6, 6, and 4 faces out of 6.

Time to Pack was expected to be the most challenging game due to the need to rotate the blocks. Indeed, P1 and P5 reported issues handling the mouse and rotating the items. The other participants did not have any problems. They completed 1, 1, 3, 3, 2, and 2 suitcases.

5 Discussion

CogWorldTravel is a serious game that has the potential to measure the cognitive performance of older adults while entertaining them both in clinical settings and remotely. The assessment of cognitive performance is particularly important for the early detection of dementia, which is beneficial for individuals, their families, and society. We expect that the introduction of game elements can alleviate the anxiety of taking a test, motivate users, and improve the user experience.

The design process was particularly challenging because of the interdisciplinary nature of this research. We had to come up with game tasks that at the same time engage and entertain, accommodate the special needs of older adults, and involve different

cognitive aspects. To accomplish all of that, we defined a set of requirements and chose to proceed with a bespoke game to satisfy them as far as possible. The relationship between the requirements, the design, and the verification method is presented in Table 1.

Table 1. Requirements, design, and verification.

Requirement ID	How the requirement is met	How the requirement is verified
1	Choice of font size	Test with older adults
2	Choice of colors	Test with older adults
3	Tasks can be completed with mouse clicks	Test with older adults
4	Choice of game tasks	Test with older adults
5	Included in familiar faces and Native fauna	Analysis by experts
6	Included in familiar faces, Padlock combination, Native fauna, and Time to pack	Analysis by experts
7	Included in familiar faces and The metro	Analysis by experts
8	Included in padlock combination	Analysis by experts
9	Included in time to pack	Analysis by experts
10	Included in messaging home	Analysis by experts
11	Choice of game tasks	Analysis by experts
12	Choice of game tasks	Analysis by experts
13	Tool delivered as a serious game	Test with older adults
14	Total and partial scores are automatically recorded	Test with older adults

In order to target the aged cohort, we defined requirements 1 to 4 and took them into consideration when designing the game. We considered that players might have low familiarity with computers and designed game tasks that do not require advanced computer skills. Most tasks can be completed only by clicking with the mouse, except for the *Time to Pack* task, where clicking with both mouse buttons and drag and drop are required. We expected players to concentrate on completing the task rather than on the user interaction. In addition, we have carefully chosen contrasting colors, avoided small font sizes, and involved older adults to ensure most average older adults would not have problems playing the game.

Requirements 5 to 10 were included to ensure the serious game would satisfy the requirements of a CSI. CogWorldTravel measures at least one aspect of the six major

cognitive domains of an individual. From the complex attention domain, sustained attention and processing speed are included. From the executive function domain, planning, working memory, overriding habits, and inhibition are included. From the learning and memory domain, immediate memory span and recent memory are included. From the language domain, expressive language is included, and receptive language is required throughout the game. From the perceptual-motor domain, visuoconstructional and perceptual-motor are included. Finally, recognition of emotions is included to represent social cognition skills. Experts in the assessment of dementia were involved to verify if the game had the potential to measure the cognitive element that it intended to measure.

Satisfying requirements 11 and 12 and designing tasks that were not reliant on literacy and language required considerable thought. We designed the tasks to be valid when translating to other languages. Except for the instructions on how to play each game task and the conversation surrounding the stated emotion in *Messaging Home*, the tasks are independent of language. We verified this by analysis with the involvement of stakeholders. We wanted the language to be involved only in the occasion of measuring this specific skill. The language-related task still needs to be validated when translating to other languages. Likewise, we attempt to design game tasks that people with any level of education could perform in a reasonably fair manner. Recognition of faces, recognition of emotions, assembly of items, memorizing highlighted stations in a metro map, and taking photos of an animal as quickly as possible are activities that do not seem to be highly influenced by education or even culture.

Other specific aspects of the game tasks required some consideration. In *Familiar Faces*, we expected that similarity among the displayed faces could affect the performance of the player. The difficulty of the task would increase if the faces included had similar age, gender, and ethnicity. In *Padlock Combination*, we were specifically concerned that people could be stuck if the words to be formed were not commonly used words. To avoid that, we decided that the person would not need to form all possible words before moving to the next set of letters. In addition, we noticed the difficulty of the task was associated with the arrangement of the set of letters. It is much easier to visualize and find words if the letters are organized in the shape of a cross when compared to if the letters were in a linear arrangement. In *The Metro*, the speed at which the stations are highlighted affects the difficulty of the task. If it is very slow, people will have to hold it in working memory for longer before starting. If it is very fast, they have a reduced chance to encode it in memory before the next one appears. In *Native Fauna*, we decided that the number of flamingos should be the same amount of A‘s in the letter A task of the MoCA if we wanted those tasks to be comparable. In *Messaging Home*, we decided that the name of the emotion needed to be clearly stated rather than allowing people to determine how they would feel about the described situation because the feelings of people may vary when facing the same situation.

We developed the tutorials for the mini-games using the Unity built-in recorder package. Before the start of each mini-game, a video and a set of instructions were shown to the player. From the interviews with the participants, we observed that video-based tutorials are confusing for the aged cohort. All participants could not differentiate the video from the actual game.

Finally, this serious game was implemented as a computer version due to COVID-19 restrictions and the possibility of testing via Zoom meeting; however, a tablet version could still facilitate further as touching the screen is more intuitive than using the mouse. Either way, both versions would allow remote administration and satisfy requirements 13 and 14.

6 Conclusion and Future Work

This paper describes the design, development, and evaluation of a serious game for cognitive screening. This new game is an example of how to involve different aspects of cognition in game tasks. CogWorldTravel focused on sampling at least one aspect of each major cognitive domain to comply with the requirement of an ideal cognitive screening instrument. In addition, our careful design ensures that the game is appropriate to be played by older adults. Age-related changes were carefully considered to provide a smooth experience to the aged cohort. The tasks included in the game are slow-paced and have simple objectives. The inputs required from the player are straightforward, which makes the game suitable for people with low familiarity with computers.

The game sample one aspect of each cognitive domain; however, not every element of each cognitive domain is included. There are many opportunities to improve CogWorldTravel. Games offer many options to test different aspects of cognition. The first improvement to this game will be the inclusion of a task to measure delayed recall, as it is an important parameter that healthcare professionals analyse during a clinical assessment. Another way of enhancing this serious game will be the development of a task to measure cognitive flexibility, which is another important aspect of the executive function. The assessment of different aspects of each cognitive domain is helpful for clinicians in differentiating diagnosis. Therefore, the development of serious games to measure as many cognitive aspects as possible is encouraged.

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