CogWorldTravel: Design of a Game-based Cognitive Screening Instrument

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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 and development of CogWorldTravel, which was an iterative process that included feedback from experts in the assessment of dementia obtained through semi-structured interviews. CogWorldTravel is a serious game that has the potential to be used for cognitive screening as it 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 towards 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].

There are several well-researched CSIs currently used to detect dementia. However, these instruments do have limitations. A relevant barrier for 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, the majority of tests are dependent on language, and scores must be validated independently in each language as it 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 to capture player interaction with the game [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].

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. Hagler *et al.* created the Scavenger Hunt, which is based on the pen-and-paper Trail Making Test [16]. Tong *et al.* proposed The Whack-a-Mole, which is inspired by the classical Go/No-Go Discrimination Task [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].

The majority of the previous studies evaluated the use of games to screen cognition by either finding their utility as an instrument to detect dementia or by correlating results with another test used as a reference. While the outcome from these studies found out to be feasible to use serious games as alternative CSIs, investigating design approaches to develop an ideal game-based CSI is still an open challenge. Commercial or well-known games are fun and engaging, but they do not comply with the requirements of traditional CSIs, specifically the need to sample all cognitive domains. In addition, commercial games 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, bespoke games offer the opportunity to explore different aspects of cognition. A range of activities can be included to assess performance on everyday tasks or assess specific domains in the same way as traditional tests. Still, previous work did not focus on including all cognitive domains.

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 and development of CogWorldTravel, a serious game for cognitive screening. 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 Section 3, CogWorldTravel is unfolded. Discussions and conclusions can be found in Section 4 and Section 5, respectively.

2 Methodology

This section describes the methodology followed to design and develop 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 design recommendations for older adults in the literature [19]. As older adults have a higher chance of presenting difficulties in hearing, vision, cognition, or mobility, we paid particular attention to the choice of colors used in the game, font size, and the complexity associated with the movements to provide inputs during gameplay. We also opted for slow-paced, simple game tasks with an intellectual challenge to avoid cognitive overload [20, 21].

In addition, we reviewed classical CSIs currently used in clinical practices to understand the items contained in those tests and which cognitive aspect 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]. The ideal instrument must sample all major cognitive domains. The cognitive domains were defined in the latest version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) as complex attention, executive function, learning and memory, language, perceptual-motor, and social cognition [1]. We also observed working definitions of each domain, examples of symptoms or observations regarding impairments in everyday activities, and examples of assessments.

The game tasks were discussed between the authors based on the above. After an initial design was agreed upon, semi-structured interviews were conducted with experts in dementia assessment to request feedback on the proposed game design. The interviews were conducted as soon as possible in the design process to incorporate feedback into the development stage. For further details on the evaluation of the serious game, please refer to [other paper].

After incorporating some of the feedback provided by the experts and the design reached more maturity, we started developing the serious game using Unity due to its versatility for developing game prototypes. The parameters designed to be collected during gameplay are stored in a CSV file. The Unity built-in recorder package supported the development of tutorials. Finally, we developed a game version to be played using a computer, which is available at https://urfriendxd.itch.io/cogworldtravel (Password available on request 13635166@student.uts.edu.au). The choice for a computer version was due to COVID-19 restrictions, as the subsequent studies would be conducted via Zoom.

3 CogWorldTravel

This section describes the design of CogWorldTravel. CogWorldTravel is a serious game that features six game tasks for cognitive assessment. Anyone can play the serious game, but it aims at accommodating age-related changes of older adults. As the name implies, travelling is the game's theme, and the game tasks are inserted in this context. The game tasks have foundations in previous research, and it was iteratively designed to include feedback from experts in the assessment of dementia.

3.1 Familiar Faces

This is the first of the game tasks. In the 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. Sets of faces will be displayed to the player. After one face is selected, the set disappears, and a new set is displayed, including faces selected before and at least one new face (see Fig. X). The player is asked to click on a new person each time to see if the person has their suitcase. The goal is to go through as many people as possible. In total, there are 50 faces in the task. The player loses when they choose someone they have checked before. The data collected during gameplay is the number of selected faces before losing the game.

The user skills required in this task are clicking on the screen, recognition memory, attention, and working memory. It means that aspects of complex attention, executive function, and learning and memory are involved. This task was inspired by the Warrington Recognition Memory Test for faces [22], which assesses recognition memory deficits. Recognition memory is an important expression of episodic memory, and its loss is a hallmark cognitive dysfunction associated with dementia. In the test, 50 faces are presented, and later the participant is challenged with a pair of faces to identify which one they have seen before. This test has been previously considered to have the ability to detect dementia [23, 24].

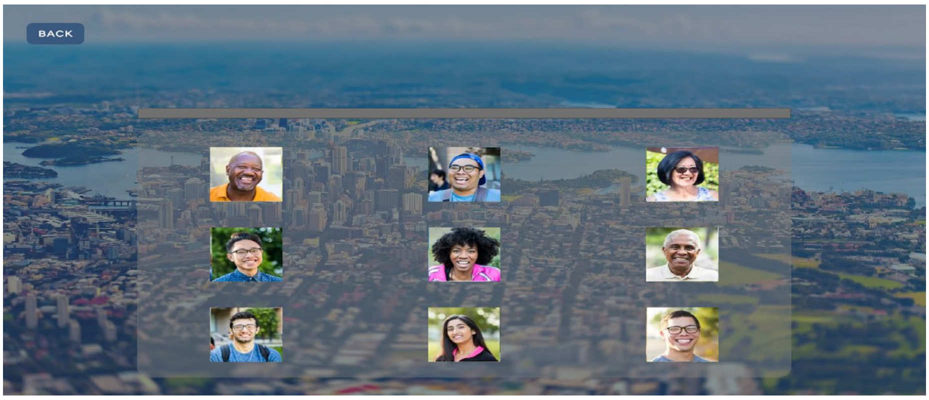

Fig. 1. Familiar Faces.

3.2 Padlock Combination

After the player retrieves the luggage, they realize they forgot the padlock combination to open it. The padlock contains a set of four letters, and the player is instructed to form as many words as they can with the given letters as an attempt to guess the right combination (see Fig. X). The play must form words of three or four letters and cannot include names. When the player forms a determined number of words with each set of letters, a new set is provided. There are no losing criteria in this task. Instead, the task is timed. The data collected during gameplay is the total number of words formed by the player within two minutes.

The user skills required in this task are clicking on the screen, language, and working memory as the player needs to hold the words already submitted in memory. It means that aspects of language and executive function are involved. 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) [25], 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.

3.3 The Metro

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 shows those spots on the map. The player must memorize the order in which the stations are highlighted in the map and click on the stations to visit them in the same order that they were highlighted (see Fig. X). The task starts with a sequence of three stations. The player is challenged with two different sequences of three stations. If at least one sequence is correctly repeated, they progress to the next level, increasing the sequence length by one station. The player loses when 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.

The user skills required in this task are clicking on the screen and immediate memory span. This task was inspired by the Corsi Blocks Test, which requires memorization of relative positions in space in temporal order. The test consists of nine square blocks positioned on a board [26]. 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 [27].

3.4 Native Fauna

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. The player goes around the screen with the mouse, which replicates the view from the lenses of a photographic camera (see Fig. X). They must click on flamingos that appear on the screen as quickly as possible. Coconuts are included as distractions, and the player must avoid taking photos of them. There are no losing criteria in this task. The player will be exposed to a defined number of targets and distractions. The data collected during gameplay include reaction time, correct photos taken (target), wrong photos taken (distraction), and missed targets.

The user skills required in this task are clicking on the screen, processing speed, inhibition, and sustained attention. It means that aspects of complex attention and executive function are involved. The task replicates the same mechanics of the letter A item from the MoCA [25], 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 [28]. 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 [29] cognitive test.

3.5 Messaging Home

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. A text conversation is shown, and feelings are mentioned. The player must 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 (see Fig. X). 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.

The user skills required in this task are clicking on the screen and recognition of emotions, which is one aspect of social cognition. Social cognitive deficits are commonly seen in people with dementia [30], even though this domain is often overlooked in classical and game-based instruments. The game task is very similar to the Emotion Recognition Task [31], 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

At the end of the trip, the player must pack their luggage before flying home. Tetraminoes-shaped items are around a suitcase, and the player must organize them inside (see Fig. X). The player may need to rotate individual items to pack everything. Once one suitcase is completed, another one will appear, and the player must complete as many suitcases as they can in two minutes. There are no losing criteria. The performance of the player is measured by the total number of suitcases completed in the given time.

This task requires the most advanced technology skills as the player must drag and drop and click with the mouse's right button while holding the left button to rotate items. Alternatively, the player can choose to press the space bar while holding the item with the mouse's left button to rotate the item. The task also involves visuoconstructional, perceptual-motor, and planning abilities, which are aspects of perceptual-motor and executive function. This task was inspired by the Tetris puzzle game, which has been considered to involve rapid visual-spatial problem-solving and motor coordination skills [32].

4 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. The choice for a bespoke game is due to the possibility of developing a set of tasks that comply with the requirements of an ideal CSI while meeting the gameplay preference of older adults for slow-paced games with intellectual challenges.

The design process of CogWorldTravel 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 that, we involved experts in the assessment of dementia in an iterative design. We wanted the game to collect cognitive information precisely while improving the experience of the person being tested. We expect that the introduction of game elements can alleviate the anxiety of taking a test and motivate users.

The serious game 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.

An aspect of the game that required considerable thought was how to design tasks that were not reliant on literacy, culture, and language. 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 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 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.

Furthermore, 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. This way, we expected players to concentrate on completing the task rather than on the user interaction. This serious game was implemented as a computer version due to COVID-19 restrictions; however, a tablet version could still facilitate further as touching the screen is more intuitive than using the mouse.

5 Conclusion and Future Work

This paper describes the design and development 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 Cog-WorldTravel. 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 executive functioning. 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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References

1. American Psychiatric, A., *Diagnostic and Statistical Manual of Mental Disorders (DSM-5®)*. 2013, Washington, UNITED STATES: American Psychiatric Publishing.
2. Rasmussen, J. and H. Langerman, *Alzheimer's Disease - Why We Need Early Diagnosis.* Degenerative neurological and neuromuscular disease, 2019. **9**: p. 123-130.
3. Larner, A.J., *Cognitive Screening Instruments: A Practical Approach*. 2013 ed, ed. A.J. Larner. 2013, London: Springer London.
4. Malloy, P., et al., *Cognitive screening instruments in neuropsychiatry: A report of the Committee on Research of the American Neuropsychiatric Association.* The Journal of neuropsychiatry and clinical neurosciences, 1997. **9**: p. 189-97.
5. Molnar, F.J., et al., *One size does not fit all: choosing practical cognitive screening tools for your practice.* 2020. **68**(10): p. 2207-2213.
6. Johnson, D., et al., *Gamification for health and wellbeing: A systematic review of the literature.* Internet Interventions, 2016. **6**: p. 89-106.
7. Martinho, D., et al., *A systematic review of gamification techniques applied to elderly care.* Artificial Intelligence Review, 2020.
8. Valladares-Rodríguez, S., et al., *Trends on the application of serious games to neuropsychological evaluation: A scoping review.* Journal of biomedical informatics, 2016. **64**: p. 296-319.
9. Gielis, K., et al. *Collecting Digital Biomarkers on Cognitive Health Through Computer Vision and Gameplay: an Image Processing Toolkit for Card Games*. in *2019 IEEE International Conference on Healthcare Informatics (ICHI)*. 2019. IEEE.

10. Intarasirisawat, J., et al., *Exploring the Touch and Motion Features in Game-Based Cognitive Assessments.* Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 2019. **3**(3): p. 1-25.
11. Sirály, E., et al., *Monitoring the Early Signs of Cognitive Decline in Elderly by Computer Games: An MRI Study.* 2015. **10**.
12. Bonnechère, B., et al., *Evaluation of cognitive functions of aged patients using video games.* 2016, ACM. p. 21-24.
13. Eraslan Boz, H., et al., *A new tool to assess amnestic mild cognitive impairment in Turkish older adults: virtual supermarket (VSM).* Neuropsychol Dev Cogn B Aging Neuropsychol Cogn, 2020. **27**(5): p. 639-653.
14. Vallejo, V., et al., *Evaluation of a new serious game based multitasking assessment tool for cognition and activities of daily living: Comparison with a real cooking task.* Computers in human behavior, 2017. **70**: p. 500-506.
15. Manera, V., et al., *'Kitchen and cooking,' a serious game for mild cognitive impairment and Alzheimer's disease: a pilot study.* Frontiers in aging neuroscience, 2015. **7**: p. 24-24.
16. Hagler, S., H. Jimison, and M. Pavel, *Assessing Executive Function Using a Computer Game: Computational Modeling of Cognitive Processes.* Biomedical and Health Informatics, IEEE Journal of, 2014. **18**: p. 1442-1452.
17. Tong, T., M. Chignell, and C.A. DeGuzman, *Using a serious game to measure executive functioning: response inhibition ability.* Applied neuropsychology. Adult, 2019: p. 1-12.
18. Valladares-Rodriguez, S., et al., *Design process and preliminary psychometric study of a video game to detect cognitive impairment in senior adults.* PeerJ, 2017. **5**: p. e3508-e3508.
19. Gamberini, L., et al., *Cognition, technology and games for the elderly: An introduction to ELDERGAMES Project.* PsychNology Journal, 2006. **4**(3): p. 285-308.
20. Chesham, A., et al., *What Older People Like to Play: Genre Preferences and Acceptance of Casual Games.* JMIR serious games, 2017. **5**(2): p. e8.
21. Machado, M.d.C., R.L.R. Ferreira, and L. Ishitani, *Heuristics and Recommendations for the Design of Mobile Serious Games for Older Adults.(Research Article).* International Journal of Computer Games Technology, 2018. **2018**.
22. Warrington, E.K., *Recognition memory test: Manual.* 1984: Nfer-Nelson.
23. Soukup, V.M., A. Bimbela, and M.C.J.J.o.C.P.i.M.S. Schiess, *Recognition memory for faces: reliability and validity of the Warrington Recognition Memory Test (RMT) in a neurological sample.* 1999. **6**(3): p. 287-293.
24. Diesfeldt, H.F.A., *Recognition memory for words and faces in primary degenerative dementia of the Alzheimer type and normal old age.* Journal of Clinical and Experimental Neuropsychology, 1990. **12**(6): p. 931-945.
25. Nasreddine, Z.S., et al., *The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool For Mild Cognitive Impairment.* Journal of the American Geriatrics Society, 2005. **53**(4): p. 695-699.
26. Corsi, P.M., *Human memory and the medial temporal region of the brain.* 1972.
27. Berch, D.B., et al., *The Corsi block-tapping task: Methodological and theoretical considerations.* 1998. **38**(3): p. 317-338.
28. Collins, L.F. and C.J. Long, *Visual reaction time and its relationship to neuropsychological test performance.* Archives of clinical neuropsychology, 1996. **11**(7): p. 613-623.

29. Yechiam, E., et al., *A formal cognitive model of the go/no-go discrimination task: evaluation and implications.* 2006. **18**(3): p. 239.
30. McCade, D., G. Savage, and S.L. Naismith, *Review of Emotion Recognition in Mild Cognitive Impairment.* Dementia and Geriatric Cognitive Disorders, 2011. **32**(4): p. 257-266.
31. Montagne, B., et al., *The Emotion Recognition Task: a paradigm to measure the perception of facial emotional expressions at different intensities.* Percept Mot Skills, 2007. **104**(2): p. 589-98.
32. Haier, R.J., et al., *MRI assessment of cortical thickness and functional activity changes in adolescent girls following three months of practice on a visual-spatial task.* BMC research notes, 2009. **2**(1): p. 174-174.