


# A theory-of-mind game for the early detection of frontotemporal dementia

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**Abstract.** People with behavioural variant frontotemporal dementia (bvFTD) struggle with social interactions and the recognition of emotions. Currently, questionnaires with pen and paper are used to diagnose people with bvFTD. In these questionnaires, people are asked to identify faux pas scenarios based on a short text. However, these questionnaires cannot convey enough emotion or realism for the test to be effective in recognizing early stages of bvFTD. We created Tommy’s Quest, a serious game to support bvFTD detection. Based on the Theory of Mind, the game gently leads players to consider what the in-game characters are thinking, as this is often challenging for people with bvFTD. Tommy’s Quest gives players an immersive feeling while answering the same type of questions as in the questionnaires currently used. However, the questions in the game are incorporated into a story which makes them less obvious. Moreover, the scenarios feel more real because they feature characters with emotions. The game generates a report based on the answers and choices of the player, to help researchers in their bvFTD diagnosis. An upcoming clinical study will be instrumental in assessing the potential of Tommy’s Quest to help clinicians improve the diagnosis of bvFTD.

**Keywords:** Serious games · Interactive narrative · Dialogue-based games · Behavioural variant frontotemporal dementia · Faux pas

## 1 Introduction

Behavioural variant frontotemporal dementia (bvFTD) is one of the leading cognitive disorders caused by neurodegeneration, in patients under 65 years of age. This cognitive disorder progressively impairs specific cognitive processes, and changes a patients’ behaviour, social conduct and emotional processing, without them recognizing that their response to a social interaction is inappropriate. Diagnosis of this disorder is currently complex, consisting of an extensive trajectory of cognitive functions, history taking, clinical observations and the tracking of behavioural and psychological symptoms over extended periods [10]. An important part of this testing trajectory is the measurement of patients’ Theory of Mind (ToM) abilities, to infer the mental state of others. ToM abilities are one of the most important markers of bvFTD, as they are the first to regress.

Currently, ToM abilities are tested by means of paper surveys taken under the guidance of a clinician, but these are less than ideal for accurate diagnosis, as they lack audio-visual elements and immersiveness. Game technologies can likely create new opportunities for clinical neuropsychology, integrating both elements [10].

We created Tommy’s Quest, a serious game aimed at empowering neuropsychology researchers in the early diagnosis of patients who are assumed to have bvFTD. This is achieved by having the patients play through an interactive narrative with scenarios that portray typical everyday social situations. The players’ responses to in-game questions are aggregated in a report, to aid researchers in their diagnosis.

## 2 Related Work

We describe related work on bvFTD and ToM. Furthermore, we briefly describe other games somehow based on ToM.

### 2.1 Theory of Mind

Theory of Mind (ToM) is the ability to impute mental states to others (encompassing many areas such as beliefs, desires, knowledge, emotions and intent) [12]. Originally coined in 1978 by Premack and Woodruff in order to research whether chimpanzees possess this ability, the term later gained traction in the field of developmental psychology when it was shown that most children under the age of five lack this ability, and is therefore developed later in life [16]. Further research also proved this ability to be lacking in individuals with certain disorders, such as autism spectrum disorder (ASD) [2], schizophrenia [14] and clinical depression [15]. Among bvFTD patients, abilities related to ToM are often impaired [11,13].

Humans with ToM (abilities) make use of three underlying mechanisms in order to infer the mental states of others [3]: *inferring actions of others*, *shared-world knowledge* and *perceiving social cues*. The first mechanism is used in order to perform false belief tasks, such as the Sally-Anne test [2] and is not necessarily lacking in bvFTD patients. However, the other two are mechanisms in which bvFTD patients are deficient.

*Shared-world knowledge* is tested by means of story-driven tasks testing intent, emotion and social awareness. Stories often involve an interaction between two or more people, in which a situation is created that is slightly out of the ordinary. For instance, stories can contain one party telling a (white) lie, being ironic, telling a joke or misreading a social situation [9]. These stories are called *faux-pas* stories and are currently used to diagnose the ToM of bvFTD patients via a questionnaire [8,6].

bvFTD patients usually also lack in *perceiving social cues*. Research into this ToM mechanism is characterised by participants performing tasks such as emotional recognition of others, or gaze detection [11]. Currently, tests like these are not used for the diagnosis of bvFTD patients, because they are more difficult to employ. However, current faux-pas (paper) tests for diagnosis mostly lack visual or audio elements. Patients who are in the early stages of bvFTD will not be lacking severely in ToM-like abilities and will therefore often be able

to perform sufficiently in these pen-and-paper tests. We pose that a game-like setting is able to more accurately convey the complexities and subtleties of social interactions.

## 2.2 Theory of Mind in games

Recognizing complexities and subtleties in social interactions requires ToM. There exist games that also require ToM to play optimally which are mostly entertainment games. One example of these games is *Hanabi*. *Hanabi* is a cooperative card game where players cannot see their own cards but only the ones from other players. By giving clues to others about their cards, the players are tasked to play their cards in a certain order. However, since the clues that are allowed do not cover the full information about the cards, ToM is needed to attain the necessary knowledge to win the game [1]. Players can do certain actions or intentionally not give certain clues which gives information in itself. So, the players should consider what others are thinking to get the most successful outcome. Because of this, *Hanabi* is a model environment for the development of artificial intelligence that possesses ToM-like abilities, for instance, using reinforcement learning [7,4].

Other examples of entertainment games centred around ToM are the games *Among Us* and *Town of Salem*. In these games, one or multiple traitors exist among the players and the non-traitors have to identify the players who are traitors. All players can perform actions and come together in social interactions. For players (traitors or non-traitors) to succeed, they will have to use ToM to either pick out suspicious players or blend in successfully.

## 2.3 Serious games for diagnosing neurodegenerative disorders

To the best of our knowledge, there have been no games proposed to aid in the diagnosis of bvFTD. However, there are serious games that aid in the diagnosis of other neurodegenerative disorders, e.g. collecting player’s data implicitly. A good example of such a game is *Sea Hero Quest* [5], which aims at identifying Alzheimer’s disease by looking at the spatial navigation of the players. The collected data in this game, logging the time and distance taken to navigate through the levels, is only visible to the researchers.

## 3 Game Design

Our design philosophy revolves around three core concepts: *realism*, *subtlety* and *simplicity*. We argue that, by adhering to these key concepts, the main goal of Tommy’s Quest can be achieved: aid clinicians assess whether the player shows signs of bvFTD through faux-pas scenarios.

*Realism* refers to the scenarios in the storyline, which resemble everyday situations. In addition, the characters in Tommy’s Quest are also realistic, resembling normal humans with different emotions, postures and facial expressions.

The core concept of *subtlety* mainly concerns how the faux-pas situations are incorporated and what the role of the player is. For the player of Tommy’s Quest, the scenarios do not have the main focus: they are just present, providing the game setting that subtly exposes the player to each faux-pas situation. Regarding

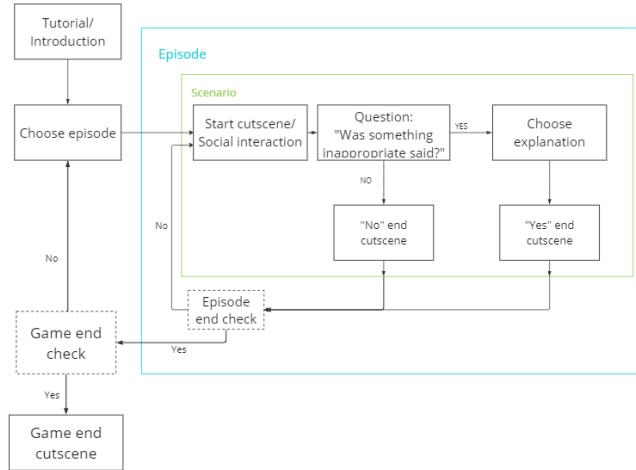


Fig. 1: The game loop

the player's role, the faux pas is never directly aimed at the player, as observing situations between two other actors is necessary to test ToM. However, the player is still engaged with the game, assuming an observing role.

Finally, *simplicity* leads Tommy's Quest to have as few distractions from the main goal as possible: the player is not burdened with complex irrelevant cognitive tasks. This also applies to the game mechanics and storyline, which are both kept simple to make Tommy's Quest accessible for all players.

### 3.1 Game loop

The game loop of Tommy's Quest (see Figure 1) consists of an introduction, a middle section containing several episodes, and finally the game ending. In the introduction (see Figure 2a), the player is introduced to the main character, Tommy, and the storyline. Also, the mechanics of clicking through the dialogue and choosing answers is introduced to the player.

After the introduction, the game enters the main game loop where the player can choose a location (episode) to go to. At this location, the player plays through multiple scenarios. During each scenario, the player is presented with a short dialogue following the storyline and is asked a couple of multiple-choice questions. The answers chosen cause the player to go to a different location or scenario.

After a few scenarios, the player is done with the episode and can choose to go to one of the remaining locations. When all locations have been visited, the player is taken to the final episode, where the story finishes and the last few questions are asked. The two dashed-line boxes in Figure 1 represent control checks run in the background, and they are transparent to the player.



(a) A scene in the introduction episode: Tommy (on the left) and his mother (on the right) are talking about where their cat could be. (b) A scene from the playground episode: Tommy (on the left) faces Pim and his mother (on the right). The player is prompted on the appropriateness of what she just said. Either answer leads to a different scene.

Fig. 2: In-game footage of example scenarios.

### 3.2 Story

In Tommy's Quest, the player follows an intriguing story. The story revolves around a boy named Tommy, who has lost his cat. In order to find his cat, Tommy goes on an adventure around the neighbourhood. During this adventure, he interacts with other people in order to find his cat. The locations where Tommy goes are the local supermarket, a playground at the nearby park, the school, and Tommy's neighbours. These locations have been chosen as they are common locations and most recognizable in everyday life. This allows the game to feel more natural and closer to everyday life. At the end of the story, Tommy finds his cat, creating a sense of happiness and accomplishment for the player.

The story is not fully linear as the player can choose where Tommy goes during the game. These decisions lead to slightly different scenarios, but these will always lead to some anchor points that are played no matter what the player chooses. This way, the player has a sense of freedom of choice in a controlled manner. Also, the player always finds the cat at the end of the game. In other words, the player always gets to the same "happy ending", regardless of the answers given during gameplay, although with a somewhat different playthrough than that of another player.

The story in general is kept very shallow and simplistic by design, as the target audience for Tommy's Quest consists of people with a potential early-stage dementia. Therefore, players are not expected to remember a complex storyline in order to play the game. However, players are expected to remember details within each scenario. For this reason, game episodes can thus also be played in any order as they are designed to be independent of each other.

In Tommy's Quest, the player is immersed but is not a protagonist of in-game conversations. The player can thus observe the (faux-pas) scenarios and reflect on them without active participation. Considering this role, we have decided to

use a main character, Tommy, that is different from the player of the game: the player will follow Tommy as he progresses through the story. We have chosen to approach the visual perspective of this game in this manner in order to consolidate two different challenges. On the one hand, the player assesses ToM-related situations between two different actors (none of them being the player). On the other hand, in order to make the game enjoyable and easy to follow for the player, the need arises for a consistent story in between different scenes, that at the same time is suitably shallow in scope to be easy to understand. By following a main character, every scene can be centred around this character, thus allowing for a consistent and progressive storyline.

### 3.3 Core game mechanics

To be able to play through the story, simple point-and-click mechanics were deemed the most suitable. Given our target audience’s age range, between 18 and 65 with an emphasis on people aged over 40, it is fair to assume that the target audience possibly has limited gaming experience but at least knows how to operate a computer mouse. Thus no familiarity with keyboard or game controller inputs is assumed. For our purposes, the smaller and simpler the set of mechanics is, the better. Otherwise, players might end up focusing on understanding and learning complicated mechanics, rather than on the actual game.

To progress the story, the player is able to go from one scenario to another. Therefore, a set of navigation mechanics is required. Since no game experience is to be expected, this navigation is simple. Additionally, the player cannot deviate from the main storyline, hence their in-game freedom with regard to navigation is limited. Allowing players to wander around would likely introduce distractions and hamper the game’s diagnosis goal. Exploring an open world is thus not an option. We found the most suitable option for navigation in Tommy’s Quest is to click buttons to proceed in the game. When prompted with a multiple-choice question, options corresponding to each answer are shown; the story will not progress until the player has input a decision, as illustrated for example in Figure 2b. During the dialogues, the player controls the pace by clicking to continue the dialogue. Clear prompts are displayed to indicate that the player can continue once they read the subtitles and are ready to move on.

Another game mechanic needed is the ability for the player to provide answers during and after observing scenarios. For instance, when the player is asked whether someone in the current scenario said something inappropriate, the player can choose either ‘yes’ or ‘no’. Each option has some context of what the consequence of choosing that option will be, as illustrated in Figure 2b. The selected answer leads the player to a different episode or scenario. Furthermore, upon a ‘yes’ answer, the player is asked to further explain their choice, by means of a multiple-choice question. The answers offered generally consist of (i) the correct option, (ii) an option that is sensible but not the intended answer, and (iii) one or more options that just do not make much sense. Only once an answer has been given, can the game continue.

Multiple choice has been selected for the player’s explanation, as opposed to asking open questions such as done in the current pen-and-paper tests, for

three main reasons: (i) requiring players' explanations for the diagnosis through open questions would break up the game flow too much; (ii) more importantly, given the constraints of the target audience, multiple choice is better suited to the diagnosis purposes, as it keeps the game mechanics simpler; we found that typing an answer to an open question would be too complicated and distracting for some; (iii) multiple-choice questions streamline diagnosis automation, since the answers do not have to be processed but rather just stored as is. So multiple choice keeps a natural game flow and allows for clear and easy diagnosis. A possible downside to multiple choice questions could be that none of the options offered corresponds exactly with the explanation that the player might come up with. However, this is mitigated by the diversity of options made available, covering sensible explanations, with which most of the players can identify with.

From a narrative perspective, the game mechanics is guiding the player through the story without judging them, thus ensuring, in a controlled fashion, that the player provides the data the researchers want to collect. Therefore, Tommy's Quest players are never punished, regardless of the answers they give.

### 3.4 Scores

With the player's answers, a score is calculated indicating how well the player masters ToM. Presently, a player can score a maximum of 18 points in total: six, for correctly identifying all non-faux-pas scenarios; the second six, for correctly identifying all faux-pas scenarios; and the final six points, for 'correctly explaining' why the faux-pas scenario is a faux pas (by choosing the correct multiple-choice option). This final score and the points per scenario are made available to the clinician, in a session log file.

## 4 Conclusion

Pen-and-paper tests currently used to assess whether a person shows signs of bvFTD, lack realism and immersion. This strongly reduces their accuracy and effectiveness. We have created Tommy's Quest, a serious game prototype that aids clinicians with this assessment. This serious game implements a novel combination of everyday scenarios and convincing visual and auditory elements. Through a careful blend of simplicity, subtlety and realism, we have incorporated a variety of faux-pas scenarios immersed in everyday situations, kept the mechanics simple and held up the enjoyability to an acceptable extent. By numerous informal playtest sessions, Tommy's Quest was well received by (healthy) participants, who found its mechanics and controls simple to grasp, and its story, immersive and appealing.

A thorough clinical evaluation of Tommy's Quest is presently being designed, with the goal of evaluating the extent to which the game improves upon current pen-and-paper questionnaires. After ethical approval of the protocol, this assessment will be performed with potential bvFTD patients, under the guidance of expert clinicians, and its results will be presented in an upcoming publication and suitable venue. Nevertheless, the intense involvement and the expert advice of neuropsychologists throughout this project make us confident in the potential of Tommy's Quest in improving the diagnosis of bvFTD.

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