MoCHA: Designing Games to Monitor Cognitive Health in Elders at Risk for Alzheimer's Disease

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Abstract
MoCHA (Monitoring Cognitive Health using Apps) is a set of tablet-based games designed to provide convenient, low-stress, affordable monitoring of cognitive health for elders at risk of developing Alzheimer's disease. Conducting psychological measurement via gameplay poses unique game-design challenges, and there are additional factors to consider when designing games for non-gamer elders who may be, or become, cognitively impaired. In this paper we briefly describe the MoCHA system, identify key design challenges, and show how specific features of the game contribute to meeting these challenges.

Author Keywords
Serious games; game design; psychometrics; games for elders; Alzheimer's disease; cognitive monitoring

ACM Classification Keywords
J.4. Social and behavioral sciences: Psychology. J.3. Life and medical sciences: Health. H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
While there is no cure for Alzheimer's disease (AD), cognitive therapies and/or drug treatments may delay

MoCHA Game #1: "Trains"

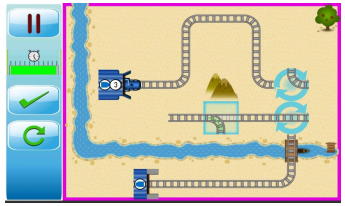

Figure 1: Simplified tutorial map. The goal of the game is to create a path between stations by tapping the manipulable (blue) tiles to rotate segments and switch junctions.

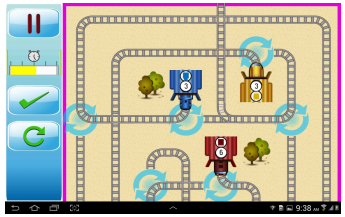

Figure 2: Difficult map. The map is larger than the viewable area, requiring the user to scroll. Each train has a matching end station, and the trains will crash if they meet enroute.

decline and improve quality of life for some patients – but only if they are started before symptoms become too severe [2, 3]. Unfortunately, most cases of AD worldwide are diagnosed later than this, if ever [5]. There is thus substantial motivation to find ways of cheaply and conveniently detecting early progression toward AD [1].

Traditional screening for cognitive impairment involves a battery of behavioral tests administered by a clinical psychologist. Even for patients identified as at risk, such tests are rarely administered more than once a year. To fill this gap, what's needed is a form of cognitive health monitoring that can be repeated on a more frequent basis, meaning that ideally it should be both inexpensive and convenient for the patient. This would not be a substitute for traditional assessment, but rather a way of identifying and notifying patients who may require full clinical evaluation.

To this end, we have developed MoCHA (Monitoring Cognitive Health using Apps), a prototype interactive psychometric system which uses gameplay to measure a range of cognitive abilities. A crucial part of this design is that the apps must be "real" games – genuinely fun, absorbing experiences with rich gameplay – not just conventional tests dressed up with a bit of gamification. At the same time, they must be accessible to an older population that may have little or no experience with video games [4]. In this paper, we discuss the design challenges associated with creating such a system, and describe some of the techniques and principles which we employed. We hope that the principles and considerations we share may be of use both to psychologists looking to harness the power of games and to game designers interested in designing for an older audience.[1]

System Overview

The core of the MoCHA system is a pair of tablet-based apps: Trains and Town Life. (See sidebars for description.) The games are implemented as local apps on an Android tablet, accessed via a launcher app which communicates with a remote server to synchronize account information, game round configurations and user gameplay data.

MoCHA is designed to be used on a regular schedule, approximately once per 2 weeks. Each session lasts about 45 minutes, during which time the user plays multiple rounds of each game, with rounds of increasing difficulty occurring in a fixed order. At the end of each round the user sees a score screen showing time taken and other game-specific criteria, as well as an overall "star rating". This score screen is designed to provide motivation and incentivize engaged play. Importantly, however, the apps do not provide any direct feedback to the user on their cognitive health or change over time. That information is extracted only on the secure central server, and would be made available only to the user's designated doctor or other qualified professional.

Design Challenges

MoCHA is designed for longitudinal monitoring; in other words, rather than providing an on-the-spot diagnosis, it's meant to track a user's cognitive health over time

[1] In this paper we focus solely on the conceptual issues surrounding psychometric game design for elders. While an empirical validation study of MoCHA has been conducted, analysis of the results is in process. Therefore, nothing in this paper should be construed as making any claims of diagnostic accuracy or of suitability for clinical use.

MoCHA Game #2:
"Town Life"

Figure 3: Town map. The user travels by dragging the car along the road. When parked in front of an area, the user can tap on it to move inside.

Figure 4: Task list. Each row shows a needy townsperson and the items they're requesting. The full list is displayed at game start; after that, only the topmost incomplete task is displayed.

and provide early warning if the user starts to show signs of decline. This means that the experience must be **repeatable** and **consistent**, such that a user with no change in cognitive health will show very similar performance from session to session. The games should also have a **short learning curve** and a clear **skill plateau** ("easy to learn, easy to master"), since improvements in the user's gameplay due to increasing skill and practice could mask changes in their underlying cognitive abilities. At the same time, the games must **remain challenging** even for experienced players, since otherwise they may become bored and play less carefully or even lose motivation to continue using the system. Even more importantly, the games must be **completable** and **non-frustrating** even for cognitively impaired players, since otherwise users experiencing cognitive decline may give up and stop using the system at precisely the point where assessment is most crucial.

To provide sensitive and specific detection of cognitive decline, the system must measure a **wide range of cognitive abilities**. While traditional neuro-psychological assessments include independent sub-tasks designed to test each ability of interest, this approach would be too time-consuming for an app designed to be used on a regular basis. Therefore, it is essential that each game be designed to test multiple cognitive abilities **simultaneously**.

Finally, since the target users of the system will be in their 50s or older, they may have limited to no experience with video games, and may even be resistant to the idea. Therefore, to the extent possible the games should be based on **age-appropriate themes**, without overly "game-y" elements (e.g. leveling up, score multipliers) or themes that some users might interpret as gender- or age-inappropriate (e.g. combat, cute pets, magic spells). Furthermore, since elderly users may have weaker eyesight and physical reflexes than younger gamers, the games should use **big, legible graphics** with **large touch targets** and should not require quick, precise movements (except where necessary for testing sensorimotor acuity).

MoCHA: Design for Psychometrics

To promote strict comparability across sessions, we structured each session as a fixed number of rounds, in a fixed difficulty order. Each round has its own time limit, so that a user who runs out of time on one round will still have the full amount of time for the subsequent rounds. The difficulty of a round is defined by strict criteria: for example, in Trains, the difficulty of a map determines how many manipulable tiles it will have and which special features (e.g. large scrollable maps, multiple trains, caves and tunnels) may appear on the map. In this way, the range of difficulty levels allows us to test the limits of users at different levels of ability, while still permitting strict comparison of performance on a given difficulty level across sessions.

While we initially explored using off-the-shelf or "classic" game types (such as card games or Dominoes), we found that these games were unsuitable for psychometrics, as they tested too few abilities at once and also tended to include significant periods of "rote" play (e.g. forced moves in Dominoes) that effectively weren't testing anything. So instead, we decided to design our own games from the ground up to maximize psychometric value. This required a time-consuming and iterative process of balancing metrics

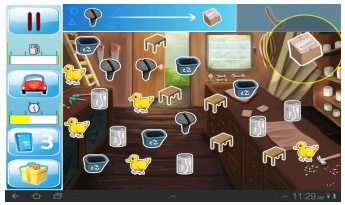

Figure 5: Inside a Town Life location. Locations can contain a variety of minigames. In this visual search minigame, the user must find all the screws and drag them into the circled box. Since there is no item collision in this minigame, physical dexterity is not a factor.

with playability and the all-important "fun factor", but in the end we were able to produce a pair of games which feel like real games (rather than thinly-veiled tests) while tracking approximately 50 distinct metrics relevant to approximately 10 different cognitive and physical abilities. A detailed review of this process is beyond the scope of this short paper, but a few examples should suffice to illustrate the strategy:

- As one measure of working memory, some Trains maps are larger than the visible display area, requiring the user to scroll if they want to see the rest of the map. The number of times the user scrolls may thus serve as an indicator of whether they're able to keep the offscreen portions of the map in memory.
- Some Trains maps contain "distractor" elements such as terrain or even a moving boat. If an experienced user attempts to interact with these elements, this may be a sign of severe confusion or disorientation. And in more routine play, if a user consistently takes longer to finish on the maps with distractors, this may suggest a deficit in attentional control.
- In Town Life, each task is associated with a delivery location and one or more puzzle locations, scattered around the map. By studying these in advance, the user can plot a path which will be far more efficient than simply visiting each location in the displayed order. Thus, on Town Life maps with a larger number of tasks, the user's total distance "driven" along the roads may provide insight into executive function.

MoCHA: Design for Engagement and Accessibility

To maximize user acceptance and engagement, we sought game themes which would draw on older players' existing knowledge and life experience. For example, while our initial concept for Town Life was set in a cheerful farming village (inspired by games like Nintendo's Animal Crossing), we realized that by setting it in a 1970s-themed town we could draw on the users' lived experience of planning errands around town, and also perhaps create some emotional resonance with a time in their lives when they were more active and independent. Trains is a somewhat more schematic and "puzzle-y" game, but still benefits from a reliance on familiar objects and simple physical metaphors; the concept of creating an unbroken track from A to B is easy to grasp, even if the track itself is quite complicated.

A second, more unusual design principle was that the user should never be able to reach a situation where they feel stuck or lost; in every situation there should always be an obvious way to make slow and steady progress. In Trains, you can always just follow the track with your finger to look for gaps, or launch the train and see where it crashes (with no penalty other than time taken); in Town Life, you can just keep pulling up your quest log and going to the next location on the list. This way, while cognitively healthy players can keep themselves engaged by trying to find faster solutions, even significantly impaired players can always fall back on simple strategies that will enable them to make progress and avoid frustration.

A third, narrower issue is how to teach users to play the game. The dominant approach, especially in mobile

and casual gaming, is to let users learn by playing, with the game starting out very easy and gradually introducing new gameplay elements over time. This approach is less suitable for a psychometric app, however, since gameplay data does not become usable until the player reaches the "steady state" at which their sessions are strictly equivalent in difficulty and complexity. In addition, for elder users, the very idea of learning through exploratory play may be unfamiliar, and clear up-front instructions provide a form of security in the face of novelty. Thus, the approach we settled on was to have direct in-person instruction coupled with a set of simplified tutorial rounds. This worked well for our purposes: the users found the "human touch" reassuring, and meanwhile it allowed us to assess whether they fully understood the games before the regular sessions began. For future scalability, however, it will be important to assess whether and how the more traditional, less labor-intensive style of in-game tutorial might be made acceptable to older players with no gaming experience.

To maximize general accessibility, we also designed the games to be language-free, and ensured that the graphics were suitable for users with common types of colorblindness or limited visual acuity. While such measures are desirable in any application, they are especially important for one which is provided directly to users rather than being selected from an app store.

Conclusion

Designing psychometric games for older players places unusual demands on game design, but our experience shows that it is possible to meet these challenges while creating games that are genuinely engaging and fun.

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