Can Card Games Be Used to Assess Mild Cognitive Impairment? A Study of Klondike Solitaire and Cognitive Functions

Karsten Gielis

KU Leuven
Andreas Vesaliusstraat 13, 3000
Leuven, Belgium
karsten.gielis@kuleuven.be

Jos Tournoy

UZ Leuven
Herestraat 49,
Leuven, Belgium
jos.tournoy@uzleuven.be

Filipa Brito

University of Lisbon
Av. Prof. Egas Moniz MB, 1649-
028 Lisboa, Portugal
filipa.r.brito@gmail.com

Vero Vanden Abeele

KU Leuven
Andreas Vesaliusstraat 13, 3000
Leuven, Belgium
vero.vandenabeele@kuleuven.be

Abstract

This paper investigates whether Klondike Solitaire can be used as an assessment tool for mild cognitive impairment (MCI). It does so by providing a structured analysis and mapping player actions to cognitive functions. For Klondike Solitaire, 22 player actions were defined and mapped to 10 cognitive functions by 3 health professionals in the field of MCI. The results indicate that Attention, Executive Function, Object Recognition, Abstraction and Memory can be assessed through gameplay of Solitaire. Healthcare professionals confirmed that this can potentially be valuable, as it can screen for cognitive impairments longitudinally, in a non-intrusive way, without practice effects.

Author Keywords

Cognitive Assessment; Solitaire; Cognitive Functions; Serious Games

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s). Copyright is held by the author/owner(s).
CHI PLAY'17 Extended Abstracts, October 15–18, 2017, Amsterdam, Netherlands

© 2017 Copyright is held by the owner/author(s).
ACM ISBN 978-1-4503-5111-9/17/10.
<https://doi.org/10.1145/3130859.3131328>

INTRODUCTION

In the past years, there has been an increasing emphasis on the early detection of mild cognitive impairment (MCI), a precursor of dementia [27]. Many studies confirm that older adults benefit from being diagnosed early [26]; this can help get the right treatment and mitigate disease progression [2,20,33]. In addition, early diagnosis ensures finding the best sources of support, as well as making informed decisions about the future [15,16,23,26]. As stated by Knapp et al. "Diagnosis is the gateway for care" [14].

Currently, many instruments exist to screen for dementia, such as the Mini-Mental State Examination (MMSE) [31] and the Montreal Cognitive Assessment (MOCA) [22]. These screening tests are by definition brief. As a consequence, for the detection of early stages of dementia and mild cognitive impairment, these tests have been reported as lacking in sensitivity [30]. It has also been reported that results of screening tests need to be interpreted with care. The patient may feel examined and stressed, or might suffer a momentary lapse, or simply be tired because the test is taken at the end of the day. In addition, it has been reported that these tests are vulnerable to practice effects [6,18,32]. These external factors hamper the validity and reliability of these screenings tests. More reliable and comprehensive cognitive test batteries do exist [24] that screen for specific cognitive functions such as attention, executive function, visuospatial skill, motor skills, memory, language, abstraction and orientation. However, the administration of these test batteries is lengthy and necessitates a trained health professional. Consequently, such a lengthy and formal assessment of cognitive decline is carried out only sporadically in older adults and requires older adults to visit a health clinic. Moreover, to

distinguish mild cognitive impairment from age-related, normal cognitive decline, specialists still need to rely on additional reports from proxies [28], such as family and professional caregivers. As a result, there is an underdetection of cognitive impairment [3,5], especially in care homes. In sum, there is a need for more reliable and frequent assessments that allow an earlier referral to a physician. Some researchers even plea for on-going cognitive assessments [4].

To fill this gap, we investigate the assessment of cognitive impairment through meaningful play. With meaningful play, we refer to games that are played often by older adults and perceived as enjoying and meaningful in and of themselves; games like card games, board games, puzzle games, etc. [9,10,21,25]. When using the term meaningful play we aim to exclude games-based assessments or suites of gamified tools that are designed specifically for cognitive assessment or rehabilitation. Rather, we aim at those games that are part of the social fabric of elderly life. These games have been appropriated by older persons [12] and while seniors do not play these games for serious/medical purposes, we aim to investigate whether these games may still be used to assess cognitive performance. We hypothesize that such games equally demand attention, memory, visuospatial processing, reasoning, and executive skills [1,7].

By using meaningful play as an assessment instrument of cognitive performance, older adults can be assessed more frequently, in a natural context, without the extra effort of doing a tedious battery of tests.

Klondike Solitaire

One game that immediately draws attention is Klondike Solitaire. Microsoft included this game in their OS since

Figure 1. Klondike Solitaire, consists of seven build stacks, four suit stacks or foundation, a pile and a talon. The goal of the game is to move all the cards to the suit stacks in the correct suit, starting from the ace to the king.

Windows 3.0 in 1990, and up to today, this remains a popular card game worldwide [19]. Solitaire is perhaps the most played game worldwide, particularly enjoyed by older adults [1,8]. The rules are simple, yet the game remains challenging: expert players only win 36.6% of the time [17]. Although founded in the 18th century when fortune-telling cards became popular [35], researchers still try to understand the optimal game strategies. Yan et al. [35] modelled Solitaire and found it to be a deterministic Markov decision problem with over 52 states, and defined a strategy to achieve a win rate of 70%. Longpré and McKenzie [17] researched how to define whether a game is winnable based on the initial deal. Given the popularity of Solitaire among older adults, in our research we aim to investigate whether the game of Klondike Solitaire can be used for continuous screening of cognitive impairment.

Related work on card games and cognitive performance
Other researchers have already investigated the use of card games for cognitive screening. Allaire et al. [1]

show that card games such as Solitaire and FreeCell do correlate with several factors indicating a more successful aging and a better cognitive and psychological functioning. Jimison et al. [13] did research on FreeCell, another Solitaire version popular in the United States. She investigated whether an older user's performance calculated based on game difficulty, number of moves, efficiency of the moves and duration of the moves. They found that based on card play they could distinguish between mild cognitive impaired users and cognitively healthy elders. Hence, these results suggest the possibility of measuring cognitive decline with card games not specifically designed for this cause. However, Jimison's research relied on Freecell, not Solitaire. Moreover, there is no further insight in what cognitive functions are specifically addressed.

Hence, a scientific foundation is needed for the hypothesis that Solitaire may be used for the assessment of MCI. Moreover, there is a need for insight in which cognitive functions may (or not) be assessed when analyzing player actions of Solitaire. Such an insight can guide multidisciplinary teams, consisting of game researchers and health professionals [11] when using Solitaire for assessment.

Therefore, in this paper we present a first structured analysis and mapping of player actions and cognitive functions, with health professionals active in the field of mild cognitive impairment and dementia.

METHOD

In order to assess whether Solitaire can be used to screen for MCI, we performed the following steps.

1: Defining Player Actions

In a series of iterations, three researchers (two PhD researchers on games and cognition, and one HCI professor) analyzed the literature on Klondike Solitaire, played the game and dissected possible player actions. After drawing up a list of actions that was found exhaustive (i.e. none of the researchers could still think of an action), these 39 actions were further analyzed. It was noted that player actions can be described at different levels of granularity: one single action (e.g. a tap), or a series of actions (flipping through the pile). Moreover, depending on the game state, player actions could be noted as neutral (player uses right hand or left hand), or as negatively valenced (e.g. a player does not make a possible move). Finally, it was also noted that some player actions were hard to interpret without understanding the (elusive) state of mind of the player. Ultimately, the decision was made to limit player actions to those that can be captured unambiguously, and that could be indicative of cognitive function (i.e. that carry valence). From the first set, 17 actions were removed. The remaining 22 player actions were defined as potentially flags for cognitive impairments which can be measured unambiguously such as “User idles a lot”, “User moves card onto a card with the same color” and “User’s scores vary by a great amount”. A full list of the player actions can be found at <https://goo.gl/bhbkXJ>.

2: Defining Cognitive Functions

In parallel, screening tools were analysed that are currently used for the screening and assessment of mild cognitive impairment (e.g. Clinical Dementia Rating (CDR) [29]). An initial list of 8 cognitive functions was drafted that are measured when screening for cognitive impairment by these tests: Attention, Executive Function, Visuospatial Skill, Motor Skills, Memory,

Language, Abstraction and Orientation. After discussing this list with a health professional as part of a pilot, it was decided to add two more cognitive functions. First, to cover user actions implicating not finding the right card, ‘Object Recognition’ was suggested. Second, for player actions involving ignoring a part of the player board, as often found in hemispatial neglect (a disabling condition caused primarily by stroke), it was suggested to add hemispatial neglect.

3: Coding of cognitive functions by health professionals

Next, three cognitive health professionals from the Memory clinic of the University Hospital of Leuven (a neuropsychologist (HP1), and a professor Gerontology and Geriatrics (HP2) and a clinical psychologist (HP3), active in the field of neuropsychology), were recruited. Each health professional received an individual introduction of 15 minutes. First, the Solitaire Game (Microsoft Solitaire Collection) was explained via a 5-minute introductory video. Secondly, a short explanation was given of the cognitive functions. After this introduction, the health professionals received a coding scheme and were asked to code every player action for the presence of the aforementioned cognitive functions. They could score between 0 (not correlated), 1 (weakly), 2 (moderately), and 3 (strongly correlated to the cognitive function). Based on the scoring of the health professionals, reliability Checks were performed. Both the Spearman’s Correlation coefficient with Spearman-Brown correction and the intra-class correlation coefficient were calculated for each Player Action (PA) as specified in [34].

The reliability proved sufficient for most actions. Except for two Player Actions (PA20 and PA22), all Spearman-Brown corrections were above 0.75 with an average of 0.80.

Table 1. Overview of player actions, cognitive functions and the average scorings of health professionals, a larger view can be found at <https://goo.gl/utkAaC>

Player Action	Spearman-Brown	Intraclass Correlation	Confidence Interval	Attention	Executive Function	Visuospatial Skill	Object Recognition	Hemineglect	Motor Skills	Memory	Language	Abstraction	Orientation
PA1. User ignores some of the stacks (especially those on the left side).	0.968	0.967	0.001	0.67	0.33	0.00	0.00	3.00	0.33	0.00	0.00	0.00	0.00
PA2. User takes a lot of time to think of a move. (Starting from last card placed to first card tapped).	0.928	0.802	0.002	2.00	2.00	0.00	0.33	0.00	0.33	0.33	0.00	1.33	0.33
PA3. User takes a lot of time to move the card (Starting from tapping a card to tapping the following card).	0.841	0.785	0.003	1.00	1.00	0.67	0.33	0.00	2.00	0.33	0.00	0.00	0.00
PA4. User flips a lot through the pile.	0.773	0.812	0.001	2.33	2.00	0.00	1.67	0.00	0.33	0.67	0.33	0.67	0.00
PA5. User does not move suitable card from the pile to the suit stack.	0.923	0.874	0.001	2.33	2.33	0.67	2.67	0.00	0.00	1.33	0.33	1.00	0.00
PA6. User does not move a suitable card from the build stack to the suit stack.	0.915	0.874	0.001	2.33	2.33	0.67	2.67	0.00	0.00	1.33	0.33	1.00	0.00
PA7. User does not move a suitable card from the pile to the build stack.	0.756	0.832	0.001	2.33	2.67	0.67	2.00	0.00	0.00	1.00	0.33	1.33	0.00
PA8. User does not move a suitable card from one build stack to another build stack.	0.799	0.848	0.001	2.67	2.67	0.67	2.00	0.00	0.00	1.00	0.33	1.33	0.00
PA9. User moves a card onto a card with the same color.	0.861	0.803	0.002	2.00	1.00	0.00	2.67	0.00	0.00	1.00	0.33	1.33	0.00
PA10. User does not place an ace immediately on the suit stacks.	0.797	0.794	0.002	2.33	2.33	0.00	1.67	0.00	0.00	1.00	0.33	1.00	0.00
PA11. User's scores vary by a great amount.	0.856	0.725	0.006	2.33	1.33	0.33	0.33	0.00	0.00	0.00	0.00	0.33	0.00
PA12. User idles a lot (Time spent doing nothing/thinking).	0.88	0.873	0.001	3.00	2.00	0.00	0.00	0.00	0.00	0.67	0.00	1.00	0.67
PA13. User has a low win ratio (which increases incrementally with difficulty level).	0.915	0.792	0.002	1.67	2.33	0.33	1.00	0.00	0.00	0.67	0.67	1.00	0.00
PA14. User presses the undo button a lot.	0.807	0.683	0.018	1.67	2.33	0.00	0.33	0.00	0.33	0.67	0.33	0.33	0.00
PA15. User forgets the goal of the challenge.	0.88	0.907	0.001	2.33	0.67	0.00	0.00	0.00	0.00	3.00	0.00	0.67	0.67
PA16. User requests a lot of hints.	0.816	0.831	0.001	1.67	2.33	0.00	0.67	0.00	0.00	0.67	0.33	1.67	0.00
PA17. User takes a very long time to finish games.	0.975	0.906	0.001	2.33	2.00	0.00	0.33	0.00	1.00	0.00	0.00	0.33	0.00
PA18. User has a lot of hints provided for him (happens after some time).	0.842	0.661	0.024	1.67	2.00	0.00	0.00	0.00	0.67	0.33	0.33	1.00	0.00
PA19. User moves a card to another card with the wrong number (E.g. placing an eight on a five).	0.692	0.652	0.001	2.33	2.67	0.33	2.33	0.00	0.00	0.33	1.33	1.67	0.00
PA20. User selects the cards with a very bad precision.	0.692	0.692	0.016	0.67	0.67	1.00	0.00	0.00	2.33	0.00	0.00	0.00	0.00
PA21. User makes bad decisions (compared to the preferred move according to professional literature).	0.902	0.826	0.001	1.00	2.67	0.33	0.33	0.33	0.33	1.00	0.33	2.00	0.00
PA22. User starts clicking on a random card with no apparent reason (with short interval, fidget tapping).	-0.41	0.185	0.336	1.67	2.00	0.33	0.33	0.00	1.00	0.67	0.33	1.00	0.67

The average Intraclass Correlation of all Player Actions is 0.79 with four player actions being under 0.70 (PA14, PA18, PA20 and PA22). Significance levels vary from <.001 to 0.019 except PA22.

4: Interview

Health professionals were encouraged to think out loud and voice their thoughts and opinions while scoring. In addition, after the mapping, further questions were

asked for clarification of their coding. We transcribed and analyzed the verbal utterances of the health professionals to provide a qualitative analysis.

RESULTS

The results of the mapping exercise can be found in Table 1. Health professionals found Attention, Executive Function, Object Recognition, Abstraction and Memory most present in the player actions. Hemi-neglect,

Language, Orientation, Motor Skills and Visuospatial Skill were found less present.

From the post-coding interviews, it became clear that all HPs believed in the possibility to measure cognitive impairments through Klondike Solitaire. They uttered that there are more cognitive functions in Solitaire than meets the eye. Yet they also noted that it remains hard to determine specifically which cognitive functions are impaired. Whereas in cognitive tests only one cognitive domain is screened at a time, during Solitaire game play multiple cognitive functions are often intertwined. Executive function and attention were noted to be most strongly correlated, and the same was stressed for object recognition and abstraction.

The format of the tool was described as unique, with elements from screenings (being an indication, low effort, not time-consuming for the caregiver) and assessments (more thorough). HP1 commented, "It will go deeper as a screening but will be less conclusive than an assessment". The fact that the game can be played daily also allows the possible detection of cognitive fluctuations, found in Lewy-body and vascular dementia. It was also noted that practice effects would be non-existent as every Solitaire game is different.

When coding the player action "User takes a long time to think of a move", the remark was made that by HP2 that 'processing speed' was lacking. While processing speed is often associated with executive functioning, it was deemed necessary to add this cognitive function separately, to be able to make the difference between the speed and the power of executive functioning. HP3 told that the problems he had defining the severity of attention and executive function would be solved with adding this cognitive function, resulting in a more uniform rating amongst coders. It was unanimously

noted among the three HPs that while the executive function often remains intact among MCI, processing speed often deteriorates. Lastly 'Apraxia', a motor disorder that tackles execution of movements, was suggested as an additional dysfunction.

DISCUSSION AND CONCLUSION

This preliminary study suggests that Klondike Solitaire has potential for the assessment of MCI. However, health professionals emphasized that it would remain hard to detect specifically which cognitive functions are impaired. Yet, this was deemed less of an issue as the goal should be to assess MCI, not to differentiate between cognitive functions. However, it became apparent that the set of cognitive functions was not complete yet when coding the player actions. Our first list of cognitive functions was based on the cognitive domains tested by the MoCA, MMSE and CDR. Health professionals indicated additional cognitive dysfunctions, such as hemispatial neglect or apraxia. Moreover, during the coding it was noted that a more fine-grained mapping should be added. In addition, some cognitive functions were not uniformly interpreted and needed a better delineation. Finally, the current study only involved 3 health professionals. Hence, it is our intent to refine and replicate this first study to more cognitive functions and more health professionals. However, we conclude that the current results support the hypothesis that Solitaire may be a useful tool for the assessment of cognitive impairment.

References

1. Jason C. Allaire, Anne Collins McLaughlin, Amanda Trujillo, Laura A. Whitlock, Landon LaPorte, and Maribeth Gandy. 2013. Successful aging through digital games: Socioemotional differences between

- older adult gamers and Non-gamers. *Computers in Human Behavior* 29, 4: 1302–1306.
2. Alzheimer's Association. 2016. *2016 Alzheimer's Disease Facts and Figures*. .
3. Emma Bartfay, Wally J. Bartfay, and Kevin M. Gorey. 2013. Prevalence and correlates of potentially undetected dementia among residents of institutional care facilities in Ontario, Canada, 2009-2011: Prevalence of potentially undetected dementia. *International Journal of Geriatric Psychiatry* 28, 10: 1086–1094.
4. S. Cahill, A. M. Diaz-Ponce, R. F. Coen, and C. Walsh. 2010. The underdetection of cognitive impairment in nursing homes in the Dublin area. The need for on-going cognitive assessment. *Age and Ageing* 39, 1: 128–131.
5. Antonio Cherubini, Carmelinda Ruggiero, Giuseppina Dell'Aquila, et al. 2012. Underrecognition and Undertreatment of Dementia in Italian Nursing Homes. *Journal of the American Medical Directors Association* 13, 8: 759.e7-759.e13.
6. Sarah A. Cooley, Jodi M. Heaps, Jacob D. Bolzenius, et al. 2015. Longitudinal Change in Performance on the Montreal Cognitive Assessment in Older Adults. *The Clinical Neuropsychologist* 29, 6: 824–835.
7. B. De Schutter, J. A. Brown, and V. Vanden Abeele. 2014. The domestication of digital games in the lives of older adults. *New Media & Society* 17, 7: 1170–1186.
8. Bob De Schutter. 2011. Never Too Old to Play: The Appeal of Digital Games to an Older Audience. *Games and Culture* 6, 2: 155–170.
9. Bob De Schutter and Vero Vanden Abeele. 2008. Meaningful Play in Elderly Life. *Proceedings of ICA 2008*,.
10. Bob De Schutter and Vero Vanden Abeele. 2010. Designing meaningful play within the psycho-social context of older adults. *Proceedings of the 3rd Int. Conference on Fun and Games*, ACM, 84–93.
11. Lindsay R Duncan, Kimberly D Hieftje, Sabrina Culyba, and Lynn E Fiellin. 2014. Game playbooks: tools to guide multidisciplinary teams in developing videogame-based behavior change interventions. *Translational Behavioral Medicine* 4, 1: 108–116.
12. Entertainment Software Association. 2016. *Essential facts about the computer and video game industry*. .
13. H. Jimison, M. Pavel, J. McKanna, and J. Pavel. 2004. Unobtrusive monitoring of computer interactions to detect cognitive status in elders. *IEEE Transactions on Information Technology in Biomedicine* 8, 3: 248–252.
14. Martin Knapp, Adelina Comas-Herrera, Ami Somani, and Sube Banerjee. 2007. Dementia: international comparisons. .
15. Christoph Laske, Hamid R. Sohrabi, Shaun M. Frost, et al. 2015. Innovative diagnostic tools for early detection of Alzheimer's disease. *Alzheimer's & Dementia* 11, 5: 561–578.
16. Bennett P. Leifer. 2003. Early Diagnosis of Alzheimer's Disease: Clinical and Economic Benefits. *Journal of the American Geriatrics Society* 51, 5s2: S281–S288.
17. Luc Longpré and Pierre McKenzie. 2009. The complexity of Solitaire. *Theoretical Computer Science* 410, 50: 5252–5260.
18. Melissa Mathews, Erin Abner, Richard Kryscio, et al. 2014. Diagnostic accuracy and practice effects in the National Alzheimer's Coordinating Center Uniform Data Set neuropsychological battery. *Alzheimer's & Dementia* 10, 6: 675–683.

19. Albert H. Morehead and Geoffrey Mott-Smith. 1983. *The Complete Book of Solitaire and Patience Games: The Most Comprehensive Book of Its Kind: Over 225 Games*. Bantam, New York.
20. Gohar Mushtaq, Nigel H. Greig, Jalaluddin A. Khan, and Mohammad A. Kamal. 2014. Status of acetylcholinesterase and butyrylcholinesterase in Alzheimer's disease and type 2 diabetes mellitus. *CNS & neurological disorders drug targets* 13, 8: 1432–1439.
21. H. H. Nap, Y. A. W. De Kort, and W. A. IJsselsteijn. 2009. Senior gamers: Preferences, motivations and needs. *Gerontechnology* 8, 4: 247–262.
22. Ziad S. Nasreddine, Natalie A. Phillips, ValÃ©rie BÃ©dirian, et al. 2005. The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool For Mild Cognitive Impairment: MOCA: A BRIEF SCREENING TOOL FOR MCI. *Journal of the American Geriatrics Society* 53, 4: 695–699.
23. Peter J. Nestor, Philip Scheltens, and John R. Hodges. 2004. Advances in the early detection of Alzheimer's disease. *Nature Medicine* 10 Suppl: S34–41.
24. Arto Nordlund, Lisbeth PÃhlsson, Christina Holmberg, Karin Lind, and Anders Wallin. 2011. The Cognitive Assessment Battery (CAB): a rapid test of cognitive domains. *International psychogeriatrics / IPA* 23, 7: 1144–1151.
25. Celia Pearce. 2008. The Truth About Baby Boomer Gamers A Study of Over-Forty Computer Game Players. *Games and Culture* 3, 2: 142–174.
26. R. C. Petersen, R. Doody, A. Kurz, et al. 2001. Current concepts in mild cognitive impairment. *Archives of Neurology* 58, 12: 1985–1992.
27. Ronald C. Petersen. 2016. Mild Cognitive Impairment: *CONTINUUM: Lifelong Learning in Neurology* 22, 2, Dementia: 404–418.
28. B. Sheehan. 2012. Assessment scales in dementia. *Therapeutic Advances in Neurological Disorders* 5, 6: 349–358.
29. Jing Ee Tan, Esther Strauss, and Elisabeth M. S. Sherman. 2011. Clinical Dementia Rating. In J.S. Kreutzer, J. DeLuca, and B. Caplan, eds., *Encyclopedia of Clinical Neuropsychology*. Springer New York, New York, NY, 587–590.
30. T. N. Tombaugh and N. J. McIntyre. 1992. The mini-mental state examination: a comprehensive review. *Journal of the American Geriatrics Society* 40, 9: 922–935.
31. Tom N. Tombaugh and Nancy J. McIntyre. 1992. The Mini-Mental State Examination: A Comprehensive Review. *Journal of the American Geriatrics Society* 40, 9: 922–935.
32. Tom N. Tombaugh and Nancy J. McIntyre. 1992. The Mini-Mental State Examination: A Comprehensive Review. *Journal of the American Geriatrics Society* 40, 9: 922–935.
33. Keith A. Wesnes, Dag Aarsland, Clive Ballard, and Elisabet Londos. 2015. Memantine improves attention and episodic memory in Parkinson's disease dementia and dementia with Lewy bodies: Memantine in Parkinson's dementia and dementia with Lewy bodies. *International Journal of Geriatric Psychiatry* 30, 1: 46–54.
34. Karl Wuensch. 2014. Inter-Rater Agreement. .
35. Xiang Yan, Persi Diaconis, Paat Rusmevichienton, and Benjamin Van Roy. Solitaire: Man Versus Machine.