MEDINFO 2023 — The Future Is Accessible
J. Bichel-Findlay et al. (Eds.)

doi:10.3233/SHTI231019

A New Role for Chatbots: Automation of a Sleep-Dependent Memory Task

David IRELAND[a,1], Aaron LAM[b], DanaKai BRADFORD[a] and Sharon NAISMITH[b]
[a]*Australian eHealth Research Centre, CSIRO, Australia*
[b]*Healthy Brain Ageing Program, School of Psychology, University of Sydney*

Abstract. Sleep is known to contribute to memory consolidation. Sleep-dependent memory is not often studied in patients with mild cognitive impairment (MCI), however, due to the need to attend sleep laboratories which are typically expensive, time-consuming and lacking in trained task administrators. We developed a conversation agent able to deliver a sleep-dependent memory task at home. Utility of the chatbot was confirmed through in-house testing and focus groups. The chatbot promises consistent task delivery and improved access for people with MCI.

Keywords. Sleep-dependent memory, automated task, chatbot, MCI

1. Introduction

Evidence supports the notion that sleep contributes to memory consolidation [1]. Sleep spindles and slow oscillations during non-rapid eye movement sleep have been linked to sleep-dependent memory [2]. Sleep changes associated with sleep disturbances and ageing have been shown to disrupt these neural oscillations and impair overnight memory consolidation [3]. Unfortunately, up to 60% of older adults with mild cognitive impairment (MCI) experience sleep disturbances [4], which have been linked to daytime memory deficits [5]. A recent meta-analysis [6] showed that there is evidence for disruption in sleep spindles in MCI compared to healthy older adults. The altered sleep spindles in MCI may result in further impairment in sleep-dependent memory, and preliminary evidence has shown that sleep-dependent memory is impacted by brain degeneration. Hippocampal volume and altered sleep spindles were associated with sleep-dependent memory performance in older adults with MCI [7].

Despite these findings, sleep-dependent memory is not routinely studied in MCI populations. There are various possible explanations for the paucity in sleep-dependent memory research compared to daytime memory. Firstly, sleep-dependent memory is assessed pre- and post-sleep, requiring participants to be in a sleep laboratory, which is expensive and time-consuming. Secondly, a lack of trained task administrators is an issue. The purpose of a sleep laboratory is to capture and assess sleep measures, rather than memory and sleep-dependent memory, meaning staff are often not trained in administering memory tasks. Thirdly, traditionally designed word-pair tasks have consisted of up to 160 pairs which can cause floor effects in clinical sample, especially those with cognitive concerns.

[1] Corresponding Author: David Ireland, email: d.ireland@csiro.au.

Our prior work demonstrated that a modified 32 word-pair task could prevent floor effects [7]. To address the other issues, we propose developing a conversation agent (chatbot) to deliver our modified word pair test as an automated sleep-dependent memory task. Ultimately, participants would be able to complete this sleep-dependent memory task at home and independently rather than in a sleep laboratory, allowing it to become more accessible for various research studies and clinical trials.

As a virtual research assistant that emulates natural conversation, a chatbot provides an engaging way of interacting with the user to administer tests and schedule follow-up notifications. Chatbots are available as apps for mobile devices (phone or tablet) downloaded from App or Play stores. Here we detail the development of a chatbot capable of collecting demographic data and engaging with the user to deliver a sleep-dependent memory task and collect both audio and text responses.

2. Methods

2.1. Chatbot Development

The chatbot was developed based on requirements arising from previous work [7], with a shared excel file to capture iterative instructions. The mobile application was developed in the Flutter framework [https://flutter.dev/] allowing a single codebase to produce functional apps for the Android and iOS operating systems.

The chatbot engine was developed to load, on start-up, a series of files that contains word synonyms, verbal responses and procedures when certain utterances are detected or events have occurred or not occurred (e.g., missed appointment). These files are commonly referred to as the brain. The word-pairs memory test was developed as a standalone widget (user interface control that displays information or provides a way for the user to interact with the device) also in the Flutter framework. The brain contains the instructions to setup the profile, provide user instructions, and display the word-pairs widget within the valid time window. It also coordinates scheduling of the notifications and procedures when a missed appointment has occurred.

2.2. Chatbot Testing In-House

Approval was sought from the CSIRO Health and Medical Human Research Ethics Committee to test the chatbot with CSIRO staff (CHMHREC 2022_56_LR). Scope of testing was limited to confirming app functionality of providing information to the user and delivering responses to an external server.

All staff (N=~120) from CSIRO's Australian eHealth Research Centre (Brisbane, Sydney, Melbourne, Perth) were invited by email to participate. Of these, consent was returned by seven staff. The initials of the user and their year of birth were collected; however, participants were encouraged to submit mock data for privacy reasons.

An abridged version of the sleep dependent memory test was provided to participants via Apple's TestFlight and Android (Internal Testing) play store. Participants were advised that total time involved should not exceed 25 minutes; that the app is to be used before going to sleep and then after waking up; and that it is only used for one period of less than 24 hours (i.e., evening and following morning). At the end of testing, participants were asked to provide any issues they encountered (e.g no notification being sent, or app crashing) by email.

Recalled words were logged on an external server, located within Australia and accessible only by the primary research team.

2.3. Data Storage

Collected data sent to a secure Cloud Firestore server (in Sydney) can be viewed by user (unique device ID), by multiple choice test or by single response tests (Figure 1).

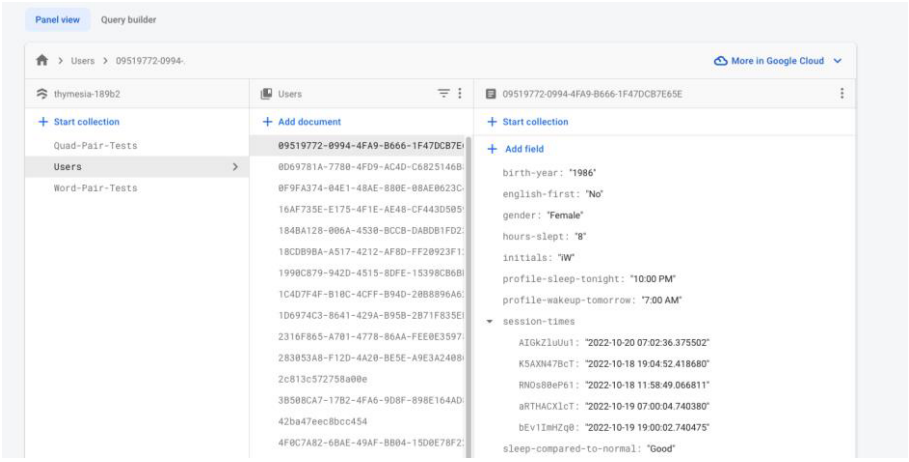

Figure 1. Data collected by the app. Phones are identified by a unique device ID, which does not provide information about the model or make of the phone; or demographics of the user.

2.4. Chatbot testing with Consumer Reference Group

Two focus groups were run by University of Sydney (USyd) with participants from the Healthy Brain Ageing reference group (N=11 in total) (USyd Human Research Ethics Committee Project No:2022/563). Focus groups ran for approximately 1.5 hours, covering a range of technology-related concepts including use of popular chat agents (Alexa), and demonstrating the sleep memory app via screenshots, with discussion.

3. Results

3.1. The Chatbot Prototype was Developed According to Specifications

The chatbot sends a notification to remind the user to undertake the evening test prior to retiring. On opening, a short survey in conversational tones was included to determine habitual waking time, and demographics of interest. The chatbot provides instructions for the test and delivers one of two alternate sets of word pairs (Figure 2). After word pairs are presented, the first word of each pair (stem words) is presented in random order for the user to provide the paired word by speech or text. Audio or text responses are recorded as transcripts, and the chatbot also has the functionality to record and store in mp3 files. The chatbot then sends a notification that the stem word test will be repeated later. At that time, the chatbot will send a notification to say it is time to complete the second stem word test. The chatbot is programmed such that the

following morning, a notification will be sent at the time determined in the initial survey reminding them to undertake the recall phase of the test. On entering the chatbot in the morning, the chatbot will greet the user in conversational tones, asking how they slept, what time they woke, and if they are ready to complete the recall test. The first word of each pair is presented in random order and responses are recorded as before.

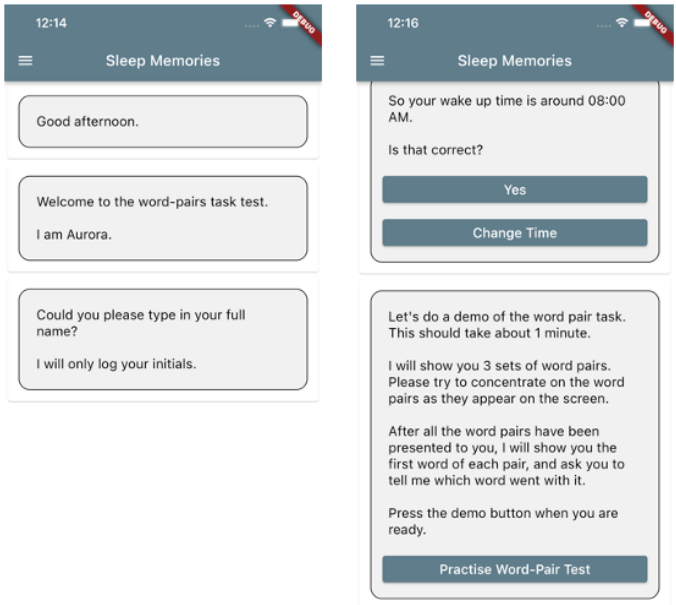

Figure 2. Screenshots of the interaction flow of the memory chatbot, demonstrating programmed functions.

3.2. The Chatbot Functionality was Confirmed During In-House Testing

All participants were able to install the mobile app on an Android or Apple phone, setup the profile and complete the memory tasks. All data of interest was captured and stored on the external database (Google Firebase) in real time (i.e., as the data was entered.). Several participants missed the required testing window and were able to negotiate a new time with the chatbot and complete both the morning and evening tests.

3.3. User Acceptability and Refinements were Confirmed by the Reference Group

Focus group participants raised no issues with the layout and design in the screenshots provided. 'Wish list' functionality included the option to defer testing to another day; feedback on task performance and/or a reward system for compliance and performance; and alternatives for push notifications (due to notification fatigue from multiple apps).

Most of the feedback from the in-house testing was user interface (UI) based. Dislike was expressed for the widget used to select the time (time-picker), small font sizes and text boxes (for inputting text). In response, the app was modified to accept time as a text entered like a digital clock in the same text box as used to enter an utterance. All other miscellaneous UI complaints were addressed (increasing size of font and text

boxes). Feedback about the app in general was positive. At this stage, the only refinement arising from the focus group feedback is to include an acknowledgement at the end of testing that responses have been received. Wish list ideas will be considered for future iterations. *"Overall, it's a nice simple app for the memory test purposes" P5*

4. Discussion

A working prototype of a sleep-dependent memory chatbot was developed to specifications and refined in accordance with in-house testing and feedback from a consumer reference group. The chatbot can obtain information from the user regarding demographics, sleep and wake times; and both provide and collect information to facilitate assessment of sleep-dependent memory. Elements from the 'wish list' will be incorporated as appropriate and the chatbot piloted in an existing clinical cohort. Limitations include lower than expected participation in testing and focus groups.

Once validated, the 32-word pair automated sleep-dependent memory test has several advantages including prevention of floor effects [7], consistent delivery, and reduction in time, inconvenience and expense for users. Support for the chatbot is provided by international collaborators who have expressed interest in incorporating the memory task into their existing sleep behaviour app.

5. Conclusions

This project demonstrates the ease and utility of automating a clinical sleep-dependent memory task, enabling consistent delivery and improved access for people with MCI.

References

[1] Stickgold R. Sleep-dependent memory consolidation. Nature. 2005 Oct;437(7063):1272-8, doi.org/10.1038/nature04286.

[2] Fogel SM, Smith CT. The function of the sleep spindle: a physiological index of intelligence and a mechanism for sleep-dependent memory consolidation. Neurosci Biobehav Rev. 2011 Apr;35(5):1154-65, doi: 10.1016/j.neubiorev.2010.12.003.

[3] Mander BA, Rao V, Lu B, Saletin JM, Ancoli-Israel S, Jagust WJ, Walker MP. Impaired prefrontal sleep spindle regulation of hippocampal-dependent learning in older adults. Cereb Cortex. 2013 Jul;24(12):3301-9, doi: 10.1093/cercor/bht188.

[4] Bloom HG, Ahmed I, Alessi CA, Ancoli-Israel S, Buysse DJ, Kryger MH, Phillips BA, Thorpy MJ, Vitiello MV, Zee PC. Evidence-based recommendations for the assessment and management of sleep disorders in older persons. J Am Geriatr Soc. 2009 May;57(5):761-89, doi: 10.1111/j.1532-5415.2009.02220.x.

[5] Wallace A, Bucks RS. Memory and obstructive sleep apnea: a meta-analysis. Sleep. 2013 Feb;36(2):203-20, doi: 10.5665/sleep.2374.

[6] D'Rozario AL, Chapman JL, Phillips CL, Palmer JR, Hoyos CM, Mowszowski L, Duffy SL, Marshall NS, Benca R, Mander B, Grunstein RR, Naismith SL. Objective measurement of sleep in mild cognitive impairment: a systematic review and meta-analysis. Sleep Med Rev. 2020 Aug;52:101308, doi: 10.1016/j.smrv.2020.101308.

[7] Lam A, Haroutonian C, Grummitt L, Ireland C, Grunstein RR, Duffy S, D'Rozario A, Naismith SL. Sleep-dependent memory in older people with and without MCI: the relevance of sleep microarchitecture, OSA, hippocampal subfields, and episodic memory. Cereb Cortex. 2021 May;31(6):2993-3005, doi: 10.1093/cercor/bhaa406.