Paper:
http://dx.doi.org/10.3233/JAD-170599
Perception and Reality of Cognitive Function: Information Processing Speed, Perceived Memory Function, and Perceived Task Difficulty in Older Adults

Anna Torrens-Burton a, Nasreen Basoudan a, Antony J. Bayer b and Andrea Tales a,∗

a Department of Psychology, Swansea University, Singleton Park, Swansea, Wales, UK
b Division of Population Medicine, Cardiff University, University Hospital Llandough, Penarth, Wales, UK

Abstract
This study examines the relationships between two measures of information processing speed associated with executive function (Trail Making Test and a computer-based visual search test), the perceived difficulty of the tasks, and perceived memory function (measured by the Memory Functioning Questionnaire) in older adults (aged 50+ y) with normal general health, cognition (Montreal Cognitive Assessment score of 26+), and mood. The participants were recruited from the community rather than through clinical services, and none had ever sought or received help from a health professional for a memory complaint or mental health problem. For both the trail making and the visual search tests, mean information processing speed was not correlated significantly with perceived memory function. Some individuals did, however, reveal substantially slower information processing speeds (outliers) that may have clinical significance and indicate those who may benefit most from further assessment and follow up. For the trail making, but not the visual search task, higher levels of subjective memory dysfunction were associated with a greater perception of task difficulty. The relationship between actual information processing speed and perceived task difficulty also varied with respect to the task used. These findings highlight the importance of taking into account the type of task and metacognition factors when examining the integrity of information processing speed in older adults, particularly as this measure is now specifically cited as a key cognitive subdomain within the diagnostic framework for neurocognitive disorders.

Keywords: Aging, information processing speed, metacognition, reaction time, subjective cognitive impairment

INTRODUCTION

Although debate continues with respect to the theoretical and applied relationship between slowing and cognition, information processing speed is a measure commonly used in research as a behavioral indicator, or proxy, of the integrity of cognitive function. The relationship is underpinned by a substantial body of evidence linking behaviorally measured change in information processing speed to brain structure (e.g., to deterioration in white and grey matter) and function in aging, mild cognitive impairment (MCI), and dementia [1–14]. The potential relevance of information processing speed in research and clinical practice is highlighted by evidence indicating that it can predict ability to perform aspects of daily activity and quality of life [15–20], and it is now specifically cited as a key cognitive subdomain within the diagnostic framework for neurocognitive disorders in DSM-5 [21].
In this study, therefore, we examine perceived memory function in relation to information processing speed in community-living older adults who have not approached health care services with concerns about their memory or cognitive function [23, 27] and with normal levels of general cognitive function and no significant anxiety or depression. In addition, as metacognition can be a factor in the self-perception of the integrity of memory and cognition [31], we also ask whether there is any relationship between reported memory performance and the perception of task difficulty (i.e., is high level of perceived memory dysfunction associated with greater perception of task difficulty?) and whether perceived task difficulty is related to actual (objectively measured) speed of information processing.

There is evidence (e.g., [5]) to suggest that the speed of information processing, and thus study outcome, can differ significantly with respect to the test used, because of the different brain networks and processes recruited by specific task demands. We therefore report studies using two different measures, the pen-and-paper-based trail making test (TMT) and a computer-administered visual search task.

The TMT is commonly used in clinical settings and in aging, MCI, and dementia research to examine information processing speed and executive function [32]. Trails A is a one-trial task typically described as probing functions such as speed of processing in relation to attention, visual scanning and search, number recognition, numeric sequencing and motor speed; giving a baseline measure of perceptual processing and motor speed. Trails B is again a one-trial task typically described as probing the efficiency of set-shifting, mental flexibility, executive function, and working memory.
Table 1

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Education (y)</th>
<th>MFQ-total score</th>
<th>Trails A (s)</th>
<th>Perceived difficulty scale for Trails A</th>
<th>Trails B (s)</th>
<th>Perceived difficulty scale for Trails B</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.5)</td>
<td>16 (4.8)</td>
<td>295 (49.1)</td>
<td>29.05 (9.3)</td>
<td>2 (1.2)</td>
<td>43.43 (9.4)</td>
<td>3 (1.6)</td>
</tr>
<tr>
<td>50–79</td>
<td></td>
<td></td>
<td></td>
<td>Range 1–6</td>
<td>Range 1–6</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 shows the demographics and TMT data for older adults. Standard deviation in parenthesis. Note that range refers to observed range within the data.

Testing took place within the Psychology Department at the University of Swansea.

Subjective memory assessment

Subjective memory function was measured using the Memory Functioning Questionnaire (MFQ) [37]. This 64-item questionnaire assesses the perception of everyday memory functioning with seven sections on general rating of memory, retrospective functioning (compares current memory with past ability), frequency of forgetting, frequency of forgetting while reading, remembering past events, seriousness of forgetting (how memory impairment impacts daily life), and mnemonics usage. Each item is scored on a 1 to 7 Likert scale (1 = severe memory problems; 7 = no problems). Scores range between 64 and 448 with high scores reflecting less severe memory complaints.

Trail Making Test

Practice trails were provided for both Trails A and B. For Trails A, the participants were instructed to draw one continuous line joining a series of circled numbers in ascending order on a sheet of paper as fast but as accurately as possible. For Trails B, the participants were instructed to draw one continuous line joining a series of circled numbers and letters alternately in ascending and alphabetical order on a sheet of paper as fast but as accurately as they could. Test outcome was the time taken in seconds to complete the test (with the time required to rectify any error forming part of the information processing speed score). No performance feedback was provided. Immediately after completing each of trails A and B, participants were asked to rate, using a scale of 1 to 7, how easy or difficult they found each test to complete, with 1 very easy to complete and 7 very difficult. Study debrief was performed at the end of the experimental session.
Table 2

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Education (y)</th>
<th>MFQ Total score</th>
<th>Information processing speed</th>
<th>Mean group errors</th>
<th>Perceived performance Likert scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Target alone</td>
<td>Target plus distracters</td>
<td>Target alone</td>
</tr>
<tr>
<td>Older adults</td>
<td>66</td>
<td>15 (3.7)</td>
<td>290 (46.5)</td>
<td>743.02 (164.91)</td>
<td>1685.55 (314.23)</td>
</tr>
<tr>
<td>(n = 54)</td>
<td>Range 55–79</td>
<td>Range 1–6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Information processing speed for both the Target alone and Target plus distracter conditions is represented by the box plot in Fig. 3. Note the presence of outliers in the performance of this task.

RESULTS

TMT: Information processing speed and subjective memory function

Spearman's correlational analysis showed no association between MFQ total score and information processing speed for either Trails A or B (all p values > 0.05). Of the seven subscales of the MFQ, none showed an association with either Trails A or Trails B (all p values > 0.05) except for a significant negative correlation of Trails A with the Mnemonics subscale (r = –0.295, p = 0.007, which survives Bonferroni correction, p = 0.042).

TMT: Information processing speed and perceived task difficulty

The mean (sd) perceived task difficulty score was 2 (1.2) with a range from 1 to 6 for Trails A and 3 (1.6) with a range of 1 to 6 for Trails B. This was not significantly correlated with performance on Trails A but was significantly positively correlated with performance on Trails B (r = 0.293, p = 0.008), with slower actual information processing speed associated with a greater perceived task difficulty.

Post hoc tests revealed that these results did not vary with respect to educational level or whether the participant was male or female.

Subjective memory function and perceived task difficulty

MFQ total score was significantly negatively correlated with perceived task difficulty for Trails A (r = –0.275, p = 0.013) and Trails B (r = –0.334, p = 0.002), with higher levels of subjective memory complaint related to greater perception of task difficulty.

Post hoc tests revealed that these results did not vary with respect to educational level or whether the participant was male or female.

STUDY 2: VISUAL SEARCH TASK:

METHODS

Participants

In the second study, another (separate) group of older adults (n = 62) were recruited. The protocol (i.e., inclusion and exclusion factors) was exactly the same as in study 1, as was the recruitment procedure. From those recruited, 6 individuals were excluded due to MOCA scores of 25 or less, with 2 further individuals excluded as a result of current poor medical health. Demographic details for the participants (n² = 54; age 50+ y; 24 male, 30 female) of this second study are shown in Table 2. All participants completed all 64 items on the MFQ.

Visual Search Task: Experimental task and procedure

For the computer-based visual search task, the time taken to respond to a target (target discrimination) when it appeared in isolation upon the screen and the time taken to respond to the same target when surrounded by seven similar but irrelevant and distracting stimuli were determined. This paradigm was presented on a Dell Precision PC running on Windows XP X86 CPU, viewed at a distance of 57 cm. All trials included a black target that was either a left- or right-pointing arrow, the task being to indicate whether the arrow was pointing to the right or left. The distracting stimuli consisted of seven black arrows that pointed up or down. A clock-face configuration (see Fig. 2) was used to position the target, both when it appeared alone and when surrounded by 7 distracters, in a counterbalanced arrangement.
in order to eliminate any differences in processing between right and left and upper and lower visual fields. A total of 64 trials were presented; the target appeared at each of the possible ‘clock-face’ locations of the trials distracters were pre-presented. For each trial the central fixation cross appeared on screen for 1000 ms prior to the appearance of the target (with or without distracters) and remained on screen until the participant responded, after which the fixation point remained on screen until the participant responded. The participants were instructed to fixate on the center cross at the beginning of each trial and to respond as quickly but as accurately as possible to whether the target was pointing to the right or left by pressing one of two computer keyboard keys. All participants were asked to reiterate the instructions to ensure understanding and then perform a practice block of no more than 10 trials. The ability of the participants to fixate on the cross at the beginning of each trial continued to be checked throughout the procedure by researcher observation. No performance feedback was provided.

Errors were calculated. Responses were eliminated if they were incorrect or obviously due to a disturbance/lapse of concentration or below a ‘natural’ reaction time therefore representing the pre-empting of the stimulus. No participants failed to respond to a trial. For each participant, the median time (information processing speed) taken to respond for the target alone and the target plus distracter trials was determined and group mean data produced (see Table 2).

**Perception of task difficulty**

Immediately after completing the test participants were asked to rate, using a Likert scale of 1 to 7, how easy or difficult they found each test to complete, with 1 very easy to complete and 7 very difficult. Study debrief was performed at the end of the experimental session.

**RESULTS**

**Visual search: information processing speed and subjective memory function**

MFQ total score and subscales scores were not significantly correlated with information processing speed for either the target alone or the target plus distracters conditions ($p$ values > 0.05). Overall errors on the visual search tasks were very small (mean group errors 0.37 for target alone and 0.33 for target plus distracters) and the number of errors was not significantly correlated with MFQ scores ($p$ values > 0.05).

![Fig. 1. Box plot of mean information processing speed (s) for Trails A and B performance in older adults.](image1)

![Fig. 2. Search stimulus.](image2)
**Information processing speed and perceived task difficulty**

The mean (sd) perceived task difficulty score for the visual search task was 3 (1.4) with a range from 1 to 6. This was significantly negatively correlated with information processing speed associated with perceived task difficulty, but not for target plus distracters conditions ($p > 0.05$). The number of errors was not significantly correlated with perceived task difficulty ($p$ values $> 0.05$).

**Subjective memory function and perceived task difficulty**

MFQ total score was not significantly correlated with perceived task difficulty for either the target alone or the target plus distracters condition ($p$ values $> 0.05$).

**Post hoc tests** revealed that all the above results did not vary with respect to whether the participant was male or female.

**Educational level and information processing speed**

Further post hoc analysis revealed that although educational level was not significantly related to subjective memory performance it was significantly positively correlated with perceived test difficulty ($r = 0.440$, $p = 0.01$) and it was significantly negatively correlated with information processing speed associated with perceived task difficulty ($r = -0.398$, $p = 0.003$) condition, but not for target alone condition ($p > 0.05$), i.e., a higher level of education is related to faster information processing speed when distractors are present.

**DISCUSSION**

The aim of these studies was to determine if a significant relationship exists between information processing speed, subjective memory function, and perceived task performance difficulty in older adults. In a difference of approach from some previous studies, we looked at people recruited from the community rather than from clinical settings, with normal general cognition and without significant depression or anxiety.

Greater levels of overall subjective memory complaint (MFQ total score) were not significantly associated with slower information processing speed as measured by the TMT or Visual Search Task. For Trails A there was a significant negative correlation between information processing speed and the mnemonics subset of the MFQ and although this survived Bonferroni correction, the significance level of this effect was low ($p = 0.042$). For Trails B and both conditions of the visual search test, information processing speed was not significantly correlated with any of the MFQ subsets.

Given the close relationship between information processing speed and white and grey matter structure [6–12], the general absence of an association with perceived memory dysfunction in otherwise cognitively healthy, euthymic older adults suggests perceived memory dysfunction is less likely to be related to structural abnormality or possible neurodegenerative change. Similarly, given the association between Alzheimer’s disease, vascular dementia and MCI and slowed information processing speed the lack of a relationship between perceived memory function and information processing speed may be indicative of a non-neurodegenerative basis for perceived impairment in individuals with ‘normal’ levels of general cognition (e.g., MoCA score within the normal range).

Note, however, that these ideas are speculative in nature given the absence of neuroimaging, a full range of objective and subjective measures of memory, cognitive and information processing speed performance, and longitudinal analysis examining the risk of developing MCI and/or dementia. The possibility that changes in brain structure and function and in memory may occur in the absence of changes in information processing speed must also be considered. Individuals also may perceive problems with memory but still perform at normal information processing speed as there may be, for some tasks, factors which influence memory and perceived memory but not information processing speed.

Nevertheless, if such findings were found to be robust after further research and development, the measurement of behavioral information processing speed might be of use in helping to determine for whom priority should be given with respect to further investigation and follow up of subjective memory complaints. For example, disproportionately slower...
Perceived memory impairment (in the absence of objective change in memory function) is related to structural change or metacognition (which is more likely to be responsive to intervention and treatment than structural change), or indeed whether a much more complex relationship exists between metacognition, structural change and actual and perceived functional integrity.

**Information processing speed and perceived task difficulty**

For Trails A, perceived task difficulty was not significantly correlated with objectively measured information processing speed. In contrast, perceived task difficulty was positively correlated with information processing speed for Trails B, i.e., slower information processing speed was associated with greater perceived task difficulty. For the target plus distracters condition of the visual search task, perceived task difficulty was not significantly correlated with objectively measured information processing speed. For the target alone condition however, perceived task difficulty was significantly negatively correlated with information processing speed, i.e., slower information speed was associated with a lower level of perceived task difficulty. This pattern of results indicates that, irrespective of perceived memory function, the judgement of task difficulty is related to the nature of the task and is not always related to actual performance.

**Educational level**

For both Trails A and B, educational level was not significantly associated with information processing speed.
In each study cohort were relatively young healthy participants (mean age 65 y). However, this is the first study to show that objective memory changes are typically more pronounced when pathological changes of neurodegenerative disease start to become more common in older age groups and in those seeking clinical care with respect to mood and personality. Further research is also required to investigate why some individuals do not approach health care services for perceived memory function. Some individuals may be anxious about a formal diagnosis and may be developing dementia and other possible reversible causes of impairments, and interventions to improve quality of life.

Participants on only one occasion and we were not able to account the possibility that performance may fluctuate, as it can be due to temporary conditions such as fatigue, or everyday stressful life events. Perceived memory was measured using only the MFQ. Related to this issue is the fact that we were not able to determine the accuracy of self-report on this measure. Furthermore, we did not include a battery of tests objectively measuring intraindividual variability, while information processing speed was measured by only two tests, both not included in relation to a variety of different tests, and the perception of task difficulty, remains to be determined in relation to a variety of different tests, and the perception of task difficulty, remains to be determined.

ACKNOWLEDGMENTS

The authors would like to thank all our participants, Dr. Jade Norris for participant recruitment, and BRACE-Alzheimer’s Research for funding part of this study.

Authors’ disclosures available online (http://j-alz.com/manuscript-disclosures/17-0599r1).

REFERENCES