Memory awareness profiles differentiate mild cognitive impairment from early-stage dementia: evidence from assessments of performance monitoring and evaluative judgement

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Abstract

Background: Measures of memory awareness based on evaluative judgement and performance monitoring are often regarded as equivalent, but the Levels of Awareness framework suggests they reflect different awareness phenomena. Examination of memory awareness among groups with differing degrees of impairment provides a test of this proposition.
Method: Ninety-nine people with dementia (PwD), 30 people with mild cognitive impairment (PwMCI), and their relatives completed isomorphic performance monitoring and evaluative judgement measures of memory awareness and were followed up at 12 and (PwD only) 20 months. In addition to the resulting awareness indices, comparative accuracy scores were calculated using the relatives' data to establish whether any inaccuracy was specific to self-ratings.
Results: When making evaluative judgements about their memory in general, both PwD and PwMCI tended to overestimate their own functioning relative to informant ratings made by relatives. When monitoring performance on memory tests, PwD again overestimated performance relative to test scores, but PwMCI were much more accurate. Comparative accuracy scores indicated that, unlike PwD, PwMCI do not show a specific inaccuracy in self-related appraisals.
Conclusions: The results support the proposition that awareness indices at the levels of evaluative judgement and performance monitoring should be regarded as reflecting distinct awareness phenomena.

Key words: appraisal, caregiver, comparative accuracy, Levels of Awareness Framework, self-awareness, self-rating

Memory awareness profiles differentiate mild cognitive impairment from early-stage dementia: evidence from assessments of performance monitoring and evaluative judgement

Scores on indices of memory awareness among people with dementia (PwD) differ depending on the assessment method used [1]. The most frequently used method of assessing memory awareness is to compare evaluative judgements about memory functioning made by the participant with parallel ratings made by an informant, usually a spouse, partner or other family member who is fulfilling the role of informal caregiver [2-4]. An alternative is to compare ratings of performance on objective tests made by the participant as tasks are completed with actual test scores [5, 6]. It has been suggested, however, that these two types of awareness index are not interchangeable indicators of a general phenomenon of memory awareness. They do not necessarily correlate [7]; they elicit different types of awareness phenomena and are therefore not directly comparable [8]. One examines the ability to monitor performance as it occurs and to detect both accurate responses and errors, while the other examines general evaluative judgements about functioning made at a more abstract level, drawn from beliefs and experiences, and the extent to which these are consistent with the judgements of an informant. The Levels of Awareness Framework [9] proposes that awareness may be examined at four levels: sensory registration, performance monitoring, evaluative judgement and meta-representation. With memory as the object of awareness, this framework clearly distinguishes performance monitoring and evaluative judgement and regards these as distinct aspects of memory awareness. Thus, the two types of awareness index may be expected under appropriate conditions to reveal different characteristics.

When making evaluative judgements about their memory, as a group, PwD rate themselves positively compared to parallel informant ratings made by informants, and this is usually considered to reflect an overestimation of functioning or ability; in comparison, healthy older controls give self-ratings that are very similar to parallel spouse or partner ratings [10]. However, ratings made by both PwD and informants are influenced by a range of psychological and social factors [9, 11, 12], making it difficult to determine how much of the apparent overestimation can be attributed to lack of awareness. It has been suggested [5] that assessment of performance monitoring may provide a more objective measure, as it does not incorporate the informant perspective, although in fact both self-ratings of task performance and task performance itself might also be subject to a range of psychological and social influences. Here again, reports suggest that PwD tend to overestimate their performance in relation to objective test scores, while healthy age-matched controls are more accurate [10, 13, 14].

Given that healthy older people with no cognitive impairment are reasonably accurate in both evaluative judgement and performance monitoring [10], the question arises as to when overestimation develops in relation to the onset of cognitive impairment, and whether it follows the same, or a different, trajectory for the two types of awareness index. In this respect, examination of awareness profiles in the heterogeneous group of older people with mild cognitive impairment (PwMCI), who have memory problems that are more extensive than expected for their age, but no evidence of dementia, would be informative. Criteria for the MCI classification [15] require not only objectively-demonstrated memory difficulty but also the presence of subjective memory complaints (SMC), which implies intact awareness. However, the available

evidence suggests that even where the SMC criterion is met, memory awareness may be compromised to some extent [16, 17], and there is considerable heterogeneity in awareness [18-20], with some findings pointing to the possibility that overestimation of functional ability may predict conversion to dementia [21]. Therefore, examination of the profile of memory awareness at the two levels of evaluative judgement and performance monitoring among PwMCI, and a comparison with healthy older people on the one hand and PwD on the other, may help to shed light, both on the nature of the processes involved and on the phenomena of awareness in MCI. Identification of different awareness profiles would support the view that the two types of awareness index do indeed reflect distinct awareness phenomena, and may in addition help to characterise different clinical groups. It would also be relevant to consider how these profiles might change over time in PwMCI and PwD, as this may help to clarify the processes involved. Relatively few studies have examined how levels of awareness change over time in dementia and the evidence from those studies that have done so is inconsistent [22], while there is a lack of evidence regarding changes in awareness over time in PwMCI [23, 24].

In order to make a direct comparison between evaluative judgement and performance monitoring, a number of methodological considerations must be addressed. It is necessary to use an isomorphic measure that assesses memory awareness in relation to the same aspects of memory across the two levels [25]. Awareness indices should be corrected for scaling effects, for example through ratio-based or similar calculations, rather than using simple difference scores [26]. Comparison with age-matched controls without cognitive impairment is important in order to establish whether scores on awareness indices in the clinical groups are outside the normal range [10].

Furthermore, it has been argued that a full account should also examine whether lack of self-rating accuracy is due to more general difficulties with accurate appraisal [26, 27]. This can be achieved by having the family member who acts as informant also complete the awareness assessment on his/her own behalf with PwD providing parallel ratings, for comparison purposes, and using the resulting data to calculate comparative accuracy scores [26]. Only where there is a specific inaccuracy in self-rating, ruling out the possibility of a global difficulty with making judgements, should a specific impairment in memory awareness be identified [26]. Again, comparison with age-matched healthy controls is needed in order to clarify whether comparative accuracy scores are outside the normal range in the clinical groups [10].

In the present study we used assessments that addressed these methodological considerations to examine the profile of memory awareness in people with MCI and with early stage dementia across evaluative judgement and performance monitoring levels. The following specific research questions were addressed:

1. What is the profile of awareness, as indexed by scores on evaluative judgement and performance monitoring assessments, for PwMCI and PwD, how does this change over time, and how does it compare to existing percentile-based normative data from healthy controls?
2. What is the comparative accuracy of PwMCI and PwD for evaluative judgement and performance monitoring, and how does this compare to existing percentile-based normative data from healthy controls?

Method

Design

The Memory Impairment and Dementia Awareness Study (MIDAS) was a longitudinal study of awareness and associated factors in people with early-stage dementia and people with mild cognitive impairment (MCI). This paper presents quantitative data for PwD, PwMCI and their family members (herein referred to as 'relatives') from the baseline assessment (Time 1), for PwD and PwMCI also from Time 2 (12 months later) and for PwD additionally from Time 3 (20 months later). Ethical approval was granted by the relevant National Health Service and University Ethics Committees. All participants gave informed consent.

Participants

Participants were recruited from Memory Clinics in North Wales, UK. Inclusion criteria for participants with dementia were a clinical diagnosis of Alzheimer's disease (AD), vascular dementia (VaD), or mixed Alzheimer's and vascular dementia according to ICD-10 criteria, and a score of 18 or above on the Mini-Mental State Examination (MMSE) [28]. Inclusion criteria for participants with MCI were that they had been classified as meeting Petersen criteria for amnestic or multiple domain MCI [29, 30]. All participants were required to have the ability to communicate verbally in English, and to have a spouse, partner or other suitable informant ('relative')available who was willing to contribute. Exclusion criteria for all participants were concurrent major depression, psychosis or other neurological disorder, and past history of neurological disorder, stroke or brain injury.

Measures

(a) Measures of neuropsychological functioning and mood

A brief neuropsychological test battery was administered to the two clinical groups. This consisted of assessments of estimated pre-morbid IQ (National Adult Reading Test, 2nd edition; NART; [31]), episodic memory (Wechsler Memory Scale, Word List Recall sub-test, immediate recall score; WMS-WL; [32]), language (Graded Naming Test; GNT; [33]) and executive function (Delis-Kaplan Executive Function System, letter and category fluency; D-KEFS; [34]). The Hospital Anxiety and Depression Scale [35] was used to assess mood.

(b) Measures of awareness

Awareness of memory performance and memory functioning was evaluated using the isomorphic procedure provided by the Memory Awareness Rating Scale (MARS; [36]; measure available for download at http://reach.bangor.ac.uk/publications), which measures both performance monitoring while completing a memory task and evaluative judgements about everyday memory functioning, with materials designed to reflect the same familiar everyday situations in each case. PwD completed the MARS at all three time points and PwMCI at Times 1 and 2, with relatives providing parallel ratings in all cases. Relatives completed the MARS with regard to their own memory, with the PwMCI or PwD providing parallel ratings, at Time 1 only.

Awareness of memory performance, as demonstrated by performance monitoring while completing a memory task, was assessed for both the participants and the informants using the Memory Performance Scale (MPS) of the Memory Awareness Rating Scale. This scale is administered alongside the Rivermead Behavioural Memory Test (RBMT), with the standard version [37] used for participants and the extended version for carers [38]. The RBMT is an ecologically-valid test of everyday memory, in which the sub-tests represent analogues of everyday situations requiring the use of memory. Respondents undertake the sub-tests of the RBMT and rate their performance on each sub-test as it is completed using the MPS. In order to take account of differing levels of performance on the objective test, a ratio score was calculated in each case by dividing the self-rating by the test score. Score values of both MPS and RBMT were first adjusted by adding 0.5 to both to allow the ratio to be calculated even when either of the values is zero. Memory performance ratio (MPR) scores close to 1 indicate close agreement between the test score and the self-rating. Scores above 1 indicate that the self-rating was greater than the test score (overestimation), while scores below 1 indicate that the self-rating was lower than the test score (underestimation). Normative data from healthy controls are available for comparison [10].

Awareness of memory functioning, as demonstrated by evaluative judgements about the use of memory in everyday situations, was assessed for both the participants and their relatives using parallel self- and informant ratings on the Memory Functioning Scale (MFS) of the Memory Awareness Rating Scale [36]. That is, the participant completed the scale on his/her own behalf (MFS-S) with the relative completing the informant ratings (MFS-I), and the relative completed the scale on his/her own behalf

(MFS-S) with the participant completing the informant ratings (MFS-I). The MFS asks for evaluative judgements of memory functioning in relation to a number of everyday situations in which memory is used; these situations are the same as those sampled in the RBMT and MPS. Higher scores indicate better perceived functioning. Difference scores were calculated in each case by subtracting the informant rating from the self-rating. To prevent scaling effects distorting measurement, the differences were divided by their means. This yielded a memory functioning discrepancy (MFD) score for the participant and for the relative. Discrepancy scores close to zero indicate good agreement between the PwD and informant. Positive scores indicate that self-rating is higher than informant rating, and vice versa. Normative data from healthy controls are available for comparison [10].

Comparative accuracy (CA) scores were calculated for performance monitoring (CA-PM) and evaluative judgement (CA-EJ) for PwD and PwMCI at Time 1 [26]. These scores indicate whether there is a tendency for participants to over- or underestimate their own ability or performance in relation to the ratings they make of the relative's ability or performance. CA scores draw upon self- and informant ratings and memory test scores. Here, two formulae were used, one focusing on self-ratings for performance monitoring and the other on self-ratings for evaluative judgement. For performance monitoring (CA-PM), the comparative accuracy formula was:

((Participant self-rating MPS/Participant RBMT score)/(Participant rating of relative MFS-I/Carer RBMT score))/((Relative self-rating MPS/Relative RBMT score)/(Relative rating of participant MFS-I/Participant RBMT score)).

For evaluative judgement (CA-EJ), the comparative accuracy formula was:

((Participant self-rating MFS-S/Participant RBMT score)/(Participant rating of relative MFS-I/Relative RBMT score))/((Relative self-rating MFS-S/Relative RBMT score)/(Relative rating of participant MFS-I/Participant RBMT score)).

A comparative accuracy (CA) score of 1 indicates perfect comparative accuracy, whereby the participant does not over- or underestimate self-ratings compared to other-ratings. In this case, while there may be over- or under-estimation, this applies to both sets of ratings and is not specific to self-ratings. Hence it cannot be interpreted as reflecting the specific inaccuracy in self-relevant judgements that would indicate impaired awareness. A CA score > 1 indicates that the participant overestimates self-rating compared to ratings of the relative. A CA score < 1 indicates that the participant underestimates self-rating compared to ratings of the relative. Where the CA score deviates markedly from 1, this indicates that self-relevant judgements are calibrated differently to judgements about others, and this may be attributed to a specific inaccuracy with regard to self-rating rather than to any global difficulty in making accurate judgements. Hence, impairments in awareness should only be considered where the CA score deviates markedly from 1. Normative data derived from calculating CA scores for healthy control couples [10] make it possible to identify the extent to which PwD and PwMCI CA scores are outside the normal range.

Procedure

Participants and relatives were visited at home by the researchers, and were each seen separately. The above measures were administered along with additional measures and an interview (not reported here). The whole assessment typically took two to

three sessions to complete at Time 1, and one to two sessions at subsequent time points.

Results

Details of the sample at each time point are summarised in Table 1. Participants at Time 1 were 99 PwD and 30 PwMCI, together with their relatives. Age, years of education and scores on the neuropsychological and mood measures are shown in Table 1. 'Relatives' of the PwD were 64 spouses/partners, 26 adult children, 6 other relatives and 3 friends (63 female; 72 co-resident with the PwD) with a mean age of 68.12 years (sd 14.01, range 33 – 89). 'Relatives' of the PwMCI were 21 spouses, 7 adult children and 2 friends (23 female and 23 co-resident with the PwMCI) with a mean age of 66.34 years (sd 11.87, range 37 – 88). At Time 2, 68 PwD and 18 MCI contributed, and at Time 3, 51 PwD were assessed (see Table 1).

(((Table 1 near here)))

Scores on the memory awareness measures for participants and relatives at Time 1 are summarised in Table 2, and scores on the evaluative judgement (MFD) and performance monitoring (MPR) awareness indices for PwMCI and PwD at all time-points are summarised in Table 3, which also provides a comparison to normative data [10]. Within each group, mean scores for each awareness measure were broadly similar across time-points. For both PwD and MCI groups we previously reported that there was no evidence of selective attrition in the MIDAS sample on the basis of age or severity of cognitive impairment [22], and confirmed using random regression

analyses [39, 40] that there was no significant change over time in evaluative judgement (MFD) scores for PwMCI [23, 24] or PwD [22]. Applying random regression analysis to the performance monitoring (MPR) scores similarly indicated that there was no significant change over time for PwMCI (slope .005 (.012), t (21.77) = .414, p = .683, CI -.019 - .029; intercept 1.477, t(36.32) = 9.544, p <.001, CI 1.16 – 1.79; variance (s.e.) for intercept Wald z = 2.86, p <.01, CI .246 - .972; random intercept, same slope) or PwD (slope .026 (.034), t(107.66) = .76, p = .447, CI -.041 - .09; intercept 4.99, t(93.20) = 4.57, p < .001, CI 2.83 – 7.16; variance (s.e.) for intercept Wald z = 7.16, p < .001, CI 73.6 – 140.36; random intercept and slope).

(((Tables 2 and 3 near here)))

The raw scores on the constituent measures of the two awareness indices (Table 2) show a consistent pattern. As expected, relatives' ratings of their own performance were similar to their objective test scores. In addition, the informant ratings made by the PwD or PwMCI groups were, on average, similar to relatives' evaluations of their own functioning. In contrast, on average, both PwD and PwMCI overestimated their performance in relation to their test scores and overestimated their functioning in relation to the relatives' ratings. The means for the evaluative judgement (MFD) and performance monitoring (MPR) awareness indices, however, offer a more nuanced picture (Table 3). These indices, unlike the raw scores, take account of the difference in each individual case between the two sets of ratings or between the ratings and objective test score. Again, as expected, relatives scored close to zero for evaluative judgement (MFD) and close to 1 for performance monitoring (MPR) , consistent with previous data from healthy controls. PwD scores were below the 1st percentile for

both evaluative judgement and performance monitoring indices at all three time-points, indicating overestimation of performance in relation to both informant ratings and objective test scores. PwMCI showed more variability. For MFD, mean PwMCI scores were below the 1st percentile at Time 1 and below the 5th percentile at Time 2, while for MPR, mean PwMCI scores were between the 5th and 10th percentiles at both time points.

These profiles were explored further by examining the distribution of individual scores across percentile rankings for PwMCI and PwD, summarised in Table 4. For PwD, across all time points, on both evaluative judgement (MFD) and performance monitoring (MPR) indices, between 65 and 72% of participants scored below the 5th percentile, equivalent to 2 or more standard deviations below the mean for the comparison group. Between 21 and 35% scored in the normal range and a very small proportion significantly underestimated their functioning or performance. For PwMCI, the pattern for evaluative judgement (MFD) was very similar, with 69 and 63% scoring below the 5th percentile at Time 1 and Time 2 respectively, approximately one-third scoring in the normal range, and very little evidence of significant underestimation. However, PwMCI showed a different pattern for performance monitoring (MPR). Only 23% scored below the 5th percentile at Time 1 and 17% scored below the 5th percentile at Time 2, with 70% and 78% scoring in the normal range respectively, and scarcely any significantly underestimated. These findings suggest that while PwD tend to overestimate on both evaluative and performance-based judgements, PwMCI are much less likely to show overestimation when making specific performance-based judgements as a task is completed than when making general evaluative judgements regarding their own memory function.

(((Table 4 near here)))

Comparative accuracy (CA) scores revealed further differences between the PwD and PwMCI groups across the two levels of awareness. These scores index the relative accuracy of self-relevant judgements in comparison to judgements about others. Mean scores are shown in Table 3. For PwD, mean comparative accuracy scores for both evaluative judgement (CA-EJ) and performance monitoring (CA-PM) were well above 1, placing the group below the 1st percentile for normal controls, and indicating a strong tendency to overestimation in self-ratings of performance or functioning compared to ratings of the relative's performance or functioning. The distribution of scores across percentile rankings (Table 5) indicated that in evaluative judgement more than half overestimated and a quarter underestimated, while in performance monitoring over half overestimated and only a small proportion underestimated. For PwMCI, however, mean comparative accuracy scores were close to 1 for CA-EJ and a perfect 1 for CA-PM, and in both cases these were within the 50th to 75th percentile range for normal controls. This indicates that in general self-ratings and other-ratings did not differ significantly in accuracy, and suggests an absence in this group of any specific inaccuracy in self-ratings that could be attributed to impaired awareness. Examination of the distribution of comparative accuracy scores across percentile ranks (Table 4) shows that in evaluative judgement, over half the MCI group underestimated self-ratings relative to other-ratings, and very few overestimated, while for performance monitoring, over half had scores within the normal range and the remainder were equally likely to over- or underestimate self-ratings relative to other-ratings.

(((Table 5 near here)))

Discussion

This study is the first to explore the profile of memory awareness in PwMCI and PwD across the two levels of evaluative judgement and performance monitoring, using indices of awareness and comparative accuracy based on an isomorphic measurement method, examining these longitudinally, and making a comparison with normative data from healthy controls. Compared to normative data, there was significant overestimation in the PwD group on both indices, in line with previous findings for PwD [2-6, 13, 14]). However, PwMCI showed different profiles on the two indices, performing similarly to PwD on the evaluative judgement index, but similarly to healthy controls on the performance monitoring index. Comparative accuracy indices confirmed that while PwD tended to overestimate self-ratings of memory functioning and memory performance relative to ratings of others, PwMCI tended to underestimate self-ratings of memory functioning relative to ratings of others when making evaluative judgements, and to show neither over- nor underestimation in performance monitoring.

These results show that there are different profiles of awareness in the two groups, which are highlighted by the use of the two types of awareness index. This may help to explain the findings from previous research that PwMCI appear to lack awareness but to a lesser extent than PwD [17] and may account for the fact that while some previous studies have identified significant overestimation of functioning among people with MCI [41, 42], others have identified considerable heterogeneity in the

presentation of awareness in this group [18, 19]. PwMCI tend to show normal performance monitoring but impaired evaluative judgement, although the impairment in the latter is less than that seen in PwD. This suggests that evaluative judgement is affected first, shedding light on the trajectory of changes in awareness indices. The comparative accuracy findings can be interpreted as showing that the impaired evaluative judgement in PwMCI reflects a general difficulty in making evaluative judgements, rather than a specific impairment in self-relevant evaluative judgements. A possible explanation is that there may be two processes involved in determining responses on awareness indices. Firstly, there is a general difficulty with broad evaluative judgements about memory ability. This is already evident in PwMCI, but immediate task monitoring is sound as PwMCI make use of feedback from the task, allowing for an accurate rating. Secondly, there is a specific difficulty with self-relevant judgements, affecting both general evaluative judgement and immediate monitoring of task performance. This is less evident in PwMCI but emerges strongly in PwD, affecting both general evaluative judgement and performance monitoring. PwD do still benefit to some extent from feedback on immediate task performance, but not to a sufficient extent to correct the overestimation [14].

Several researchers have observed that, in contrast to the more typical pattern of overestimation, some PwD rate themselves more negatively than other-ratings or task performance would suggest, and this has been referred to as the phenomenon of 'hyperawareness' or 'hypergnosia' [43]. This carries the implication that in contrast to the reduced awareness that is more commonly seen, these individuals have a heightened awareness of their own ability or performance. In fact ratings that are markedly discrepant in either direction reflect inaccurate appraisals, and hence it is

not necessarily appropriate to equate underestimation with increased awareness. Furthermore, the reasons for underestimation may be different to those contributing to overestimation. The present results show that when scores on awareness indices are considered in the context of normative data, self-ratings that are markedly more negative than other-ratings or task performance scores are rare among both PwMCI and PwD. However, PwMCI who have a general difficulty with judgements in the absence of impaired awareness may tend to give ratings that underestimate their functional ability, perhaps reflecting a tendency to make more pessimistic judgements about their abilities. It could be inferred that this pattern might be related to experiencing loss of confidence or other negative psychological reactions to the developing memory impairment [44, 45]. Consistent with this, one study found that in relation to everyday functioning PwMCI reported more changes than did their relatives, whereas PwD reported fewer changes than relatives [46]. Some PwD show a similar pattern, although it appears to be much less common in this group.

The demonstration of different profiles for the two awareness indices suggests that they do reflect distinct awareness phenomena. While it is important to bear in mind that psychological and social influences shape the expression of awareness, requiring a biopsychosocial perspective in understanding awareness phenomena, it is also important to consider which cognitive processes underpin these two distinct phenomena. In a recent review [47], the Levels of Awareness Framework [9] has been linked with the reformulated Cognitive Awareness Model of awareness in Alzheimer's disease [48], suggesting the operation of different cognitive processes at each level. Performance monitoring draws on the ability to detect errors and by a process of comparison to identify these as such; this lies in the domain of behavioural

regulation and relates closely to executive function. The process of making evaluative judgements, in contrast, requires the ability to integrate current information about one's own functioning with existing knowledge about the self, and relies heavily on the operation of episodic and autobiographical memory.

The identification of distinct awareness phenomena has implications for the methods adopted in awareness research. Awareness indices derived from evaluative judgement discrepancy scores and performance monitoring discrepancy scores should not be considered interchangeable or directly comparable. The two assessment methods provide similar information in the situation where there is either no cognitive impairment, as with healthy older controls, or extensive cognitive impairment, as with PwD, but different profiles emerge where the impairments are more subtle, as in the case of PwMCI. Future research could examine further the processes involved in making these different kinds of judgements, how these processes are affected in PwMCI and PwD, and how they change over time in each case. .

The findings also have clinical implications. The comparative accuracy evidence suggests that PwMCI, as a group, should not be assumed to show unawareness, although clearly there are individual differences. In clinical settings, and indeed in everyday life, whether PwMCI are regarded as lacking awareness will depend on whether the assessment is based on their general evaluative judgements (which are less likely to be accurate) or their view of how they managed in a particular situation (which is more likely to be accurate). PwMCI are likely to be able to act on and respond to immediate feedback when monitoring their performance. It is important to note, however, that there is individual variability within both PwMCI and PwD

groups. Previous research on awareness in MCI in particular has emphasised that PwMCI vary considerably in levels of awareness and ability to make accurate self-appraisals in various domains [18, 19, 49]. The present study demonstrates that a minority of PwMCI show a pattern that is more like that of the majority of PwD, and it would be of interest to investigate whether and how this relates to the likelihood of progression to dementia. In connection with this, studies have suggested that in PwMCI overestimation of functional ability as compared to informant report may be a predictor of progression to dementia [21].

The absence of change in awareness indices over time for both PwMCI and PwD meant that the two groups were still differentiated one year after initial assessment. For PwMCI, it is possible that there was selective withdrawal of those whose condition was worsening, and two participants who had progressed to dementia were withdrawn at Time 2; this ensured that the group remained clearly an MCI group and hence it is not surprising that there was still a clear differentiation from the dementia group at Time 2. For PwD, average scores on the awareness indices already showed a floor effect at Time 1, when they were below the 1st percentile, so there was little scope to demonstrate significant further decline; however, the proportion scoring in the normal range remained similar across all three time points, suggesting that once the initial pattern whereby about two-thirds of PwD overestimate their ability or performance has been established, there is a degree of stability in awareness scores. What remains to be determined is when and how both evaluative judgement accuracy and performance monitoring accuracy decline in PwMCI and how the decline in performance monitoring accuracy in particular relates to the progression to dementia.

There are a number of limitations that must be taken into account when interpreting these findings. Both clinical groups demonstrated a degree of heterogeneity. The nature of MCI is that only a proportion of PwMCI will progress to dementia [50-52]. However, a strength of the study is that PwMCI were clinically diagnosed rather than being drawn from a community sample; this may have produced a group of individuals who were likely to express subjective memory complaints and hence, to demonstrate some awareness of memory difficulties [53], but nevertheless there was considerable variability in awareness scores. The PwD group included people from a mixture of diagnostic categories, with Alzheimer's, vascular and mixed dementia represented; however, no differences were found between these three groups on any measure used in the MIDAS study, and therefore it was considered appropriate to collapse the data for analysis. Furthermore, while cross-sectional comparison of MCI and PwD groups proved informative, a clearer perspective would be gained by following PwMCI over time. This would make it possible to establish the relationship between changes in awareness and progression to dementia.

From a methodological perspective, comparative accuracy scores draw upon self- and informant ratings and memory test scores, but there was a slight asymmetry in the formulae for performance monitoring (CA-PM) and evaluative judgement (CA-EJ). While the evaluative judgement (CA-EJ) formula draws on self- and informant ratings for evaluative judgement made on the memory functioning scale, the performance monitoring (CA-PM) formula draws on self-ratings for performance monitoring made on the memory performance scale and informant ratings for evaluative judgement made on the memory functioning scale. The isomorphic nature of the two scales means that they can readily be combined in this way, with the evaluative judgement

ratings effectively serving as a prediction of task performance [10]. Using this method was a pragmatic solution as it was not considered feasible for informants to observe and rate memory test performance, and participants may not have found this acceptable. Such a procedure could likely be carried out only with a very select participant group; however, it would be of interest in future research to explore whether this approach would yield the same pattern of results.

Conclusions

This study is the first to directly compare awareness profiles using evaluative judgement and performance monitoring indices and comparative accuracy scores in PwMCI and PwD. The findings demonstrate that, as predicted on the basis of the theoretical model, there is a dissociation between the two levels of awareness, suggesting that assessments at these two levels should be regarded as reflecting distinct awareness phenomena. The findings shed light on the nature of memory awareness in PwMCI, contribute to an understanding of the heterogeneity that has been observed with regard to awareness in this group, and help to identify the ways in which the processes involved in making evaluative judgements and monitoring performance may start to break down as cognitive impairment develops and progresses.

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Table 1. Mean scores for demographic variables, neuropsychological tests and mood measures (mean, sd, range) for PwMCI and PwD groups across all time points

	MCI T1 N = 30	MCI T2 N = 18	PwD T1 N = 99	PwD T2 N = 68	PwD T3 N = 51
Age	76 (8.55; 60 – 97)	77.72 (8.22; 66 – 98)	78.71 (7.79; 51 – 91)	78.5 (8.60; 52 – 92)	78.61 (7.82; 56 – 92)
Years of education	10.68 (1.93; 6 – 14)	10.86 (2.25; 6 – 14)	11.76 (2.64; 8 – 19)	11.97 (2.75; 8 – 19)	11.76 (2.42; 8 – 17)
MMSE (max 30)	25.9 (3.45 18 – 30)	26.17 (3.76; 15 – 30)	24.13 (2.81; 18 – 30)	22.71 (4.74; 8 – 30)	21.61 (5.35; 6 – 30)
NART errors (max 50)	21.37 (10.2; 1 – 37)	19.39 (11.02; 1 – 37)	18.94 (9.55; 3 – 45)	18.82 (9.54; 6 – 45)	17.92 (8.70; 6 – 45)
WMS-WL Total trials 1 - 4	19.63 (6.37; 7 – 35)	19.22 (8.58; 10 – 37)	15.32 (6.22; 3 – 35)	15.49 (7.24; 1 – 40)	13.85 (6.28; 0 – 28)
GNT (max 30)	17.37 (5.15; 5 – 25)	17 (6.56; 4 – 28)	13.07 (6.59; 0 – 27)	12.42 (6.91; 0 – 26)	12.30 (7.47; 1 – 26)
D-KEFS LF (f/a/s)	32.69 (14.19; 9 – 70)	31.56 (16.04; 7 – 65)	28.87 (13.22; 5 – 62)	27.15 (13.70; 1 – 67)	30.16 (13; 5 – 72)
D-KEFS CF	26.86 (9.38; 7 – 45)	25.39 (9.25; 14 – 47)	20.61 (8.20; 2 – 40)	18.85 (8.53; 2 – 37)	20.09 (7.99; 6 – 40)
HADS-Anxiety (max 21)	4.6 (4.17; 0 – 17)	5.44 (4.25; 1 – 18)	5.55 (4.02; 0 – 18)	5.57 (3.41; 0 – 14)	5.51 (3.41; 0 – 19)
HADS-Depress (max 21)	3.97 (2.62; 0 – 11)	3.67 (2.63; 0 – 9)	4.33 (3.41; 0 – 17)	4.49 (3.40; 0 – 14)	4.41(3.04; 0 – 13)

MMSE: Mini-Mental State Examination; NART: National Adult Reading Test; WMS-WL: Wechsler Memory Scale, Word List Recall sub-test; GNT: Graded Naming Test; D-KEFS LF and CF: Delis-Kaplan Executive Function System, Letter Fluency and Category Fluency sub-tests; HADS: Hospital Anxiety and Depression Scale

We previously reported that there were no differences on any measure among the dementia diagnostic sub-groups (Alzheimer's, vascular and mixed dementia) in scores on awareness indices or any other measures, and hence the data were collapsed across diagnostic groups for purposes of analysis [54].

For the PwD group, we also previously reported significant decline over the three time points in MMSE score, memory, naming, and category fluency only. For the PwMCI group, we previously reported significant decline over the two time points for memory, letter fluency and category fluency only [22-24].

Table 2. Mean scores on MARS components and memory awareness indices at Time 1 for PwD, PwMCI and relatives (mean, sd, range)

	PwMCI N = 30	Relatives of PwMCI N = 30	PwD N = 99	Relatives of PwD N = 84[a]
MFS-S	39.00 (7.37; 23 – 50)	44.18 (4.57; 34 – 52)	35.15 (8.40; 10 – 52)	43.41 (5.80; 15 – 52)
MFS-I	24.9 (10.04; 4 – 42)	46.11 (5.12; 36 – 52)	20.51 (11.08; 0 – 48)	46.16 (5.85; 26 – 52)
MFD	.48 (.48; -.32 – 1.6)	.05 (.13; -.29 - .27)	.58 (.61; -1.13 – 2)	.06 (.17; -.44 - .59)
MPS	33.57 (7.48; 20 – 48)	32.6 (7.18; 17 – 45)	24.71 (8.60; 5 – 45)	32.43 (7.39; 12 – 47)[b]
RBMT or RBMT-E SPS	11.9 (5.63; 0 – 22)	32.08 (6.32; 20 – 42)	5.36 (5.92; 0 – 22)	30.30 (7.95; 12 – 48)[b]
MPR	1.47 (.85; .65 – 5)	1.02 (.15; .61 – 1.28)	5.01 (11.26; .71 – 75)	1.11 (.29; .67 – 2.42)[b]

[a] *84 PwD provided informant ratings in respect of their relatives*

[b] *n = 74. Seventy-four of the 84 relatives for whom informant ratings were available on MFS also completed the MPS and RBMT-E.*

MFS-S: Memory Functioning Scale, Self-rating; MFS-I: Memory Functioning Scale, Informant rating; MFD: Memory Functioning Discrepancy; MPS: Memory Performance Scale; RBMT(-E) SPS: Rivermead Behavioural Memory Test (Extended) Standardised Profile Score; MPR: Memory Performance Ratio.

For MFD, the relatives' mean in both groups is between the 25th and 50th percentiles. For MPR, the mean for relatives of PwMCI is between the 50th and 75th percentiles and the mean for relatives of PwD is between the 25th and 50th percentiles.

Table 3. Mean scores on memory awareness indices across all time points and comparative accuracy indices for PwMCI and PwD groups at Time 1, with comparison to normative data

	PwMCI			PwD		
	Mean sd, range	%ile	n	Mean sd, range	%ile	n
MFD Time 1	.48 .48, -.32 – 1.6	<1	29	.58 .61, -1.13 – 2	<1	99
MFD Time 2	.35 .55, -.94 – 1.58	1 - 5	16	.58 .65, -1.11 – 2	<1	68
MFD Time 3				.64 .70, -1.64 – 2	<1	51
MPR Time 1	1.5 .94, .65 – 5.5	5 - 10	30	5.01 11.26, .71 – 75	<1	95
MPR Time 2	1.47 .85, .65 - 5	10	18	3.70 3.54, .78 – 19	<1	65
MPR Time 3				3.95 5.31, .81 – 31	<1	49
CA- EJ Time 1	.89 1.26, .20 – 6.47	50 - 75	24	6.91 12.49, .06 – 72.83	<1	67[a]
CA-PM Time 1	1 .98, .17 – 4.94	50 - 75	24	5.15 10.18, .12 – 65.08	<1	67[a]

[a] *There were 67 participant-relative dyads in the PwD group which completed all aspects of the MARS procedure, allowing calculation of the CA score.*

MFD: Memory Functioning Discrepancy; MPR: Memory Performance Ratio; CA-EJ: Comparative Accuracy – Evaluative Judgement; CA-PM: Comparative Accuracy – Performance Monitoring

For PwMCI, 17 were male and 7 female, so norms for men as respondents were used when comparing CA to control data. For PwD, all mean scores were below the 1st percentiles for both male and female controls.

Table 4. Percentile ranked MFD and MPR scores in the PwMCI and PwD groups at each time point: numbers scoring at each level

	PwMCI				**PwD**					
	MFD T1 N = 29	MFD T2 N = 16	MPR T1 N = 30	MPR T2 N = 18	MFD T1 N = 99	MFD T2 N = 68	MFD T3 N = 51	MPR T1 N = 95	MPR T2 N = 65	MPR T3 N = 49
>95	0	1	2	1	7	4	2	3	1	0
90-95	2	1	0	0	0	2	3	1	1	2
75-90	0	0	4	2	3	1	0	4	5	2
50-75	2	0	4	7	9	2	1	9	4	3
25-50	1	1	5	1	4	6	3	4	5	2
10-25	2	2	5	2	4	3	2	7	1	6
5-10	2	1	3	2	1	1	5	3	4	2
<5	20	10	7	3	71	49	35	64	44	32
% scoring above 95th %ile	0%	6%	7%	5%	7%	6%	4%	3%	1%	0%
% scoring in normal range	31%	31%	70%	78%	21%	22%	27%	30%	31%	35%
% scoring below 5th %ile	69%	63%	23%	17%	72%	72%	69%	67%	68%	65%

MFD: Memory Functioning Discrepancy; MPR: Memory Performance Ratio.

The 50th percentile indicates close agreement between participant and informant (MFD) or close similarity between self-rating and test score (MPR). Scores in the low percentile range reflect overestimation by the participant in relation to either informant rating or test score, while scores in the high percentile range reflect underestimation by the participant in relation to either informant rating or test score.

Table 5. Percentile ranked comparative accuracy (CA-EJ and CA-PM) scores for PwD and PwMCI groups at Time 1: numbers scoring at each level

Percentile	PwMCI n = 24 (7f, 17m)		PwD n = 67 (37f, 30m)	
	CA-EJ	CA-PM	CA-EJ	CA-PM
>99	10	3	12	2
95-99	3	2	4	5
90-95	2	6	1	7
75-90	2	3	2	1
50-75	4	2	4	3
25-50	1	3	5	4
10-25	0	0	1	3
5-10	0	0	0	2
1-5	1	2	2	1
<1	1	3	36	39
% scoring at or above 95th percentile	54%	21%	24%	10%
% scoring in normal range	38%	58%	19%	30%
% scoring at or below 5th percentile	8%	21%	57%	60%

There were 67 participant-relative dyads in the PwD group which completed all aspects of the MARS procedure, allowing calculation of the CA score.

CA-EJ: Comparative Accuracy – Evaluative Judgement; CA-PM: Comparative Accuracy – Performance Monitoring

CA-EJ is equivalent to CA-prediction and CA-PM to CA-postdiction in [10].Underestimation relative to other rating is indicated by scores falling at the upper end of the percentile range. Overestimation of self-rating relative to other rating is indicated by scores falling at the lower end of the percentile range. Gender-specific norms [10] were used to determine each participant's percentile ranking.