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ABSTRACT

Objectives: People with amnestic Mild Cognitive Impairment (aMCI) or dementia often exhibit a decline in their social abilities, but few tests of social cognition exist that are suitable for clinical use. Moreover, the relationship between changes in behaviour and impairments in social cognition is poorly understood. We examined the utility of the Edinburgh Social Cognition Test (ESCoT) in people with aMCI/dementia and explored associations between social cognition performance and behaviour changes.

Methods: We administered the ESCoT and two established social cognition tests (Reading the Mind in the Eyes; RME and the Social Norms Questionnaire; SNQ) to 28 people with aMCI or dementia and 28 age and sex matched cognitively healthy controls. Behaviour change was measured using a semi-structured interview which assesses behavioural abnormalities found in frontotemporal dementia.

Results: People with aMCI/dementia were impaired on the ESCoT affective ToM, ESCoT total score and the RME. Behaviour changes in the domains of apathy, loss of sympathy/empathy, perseveration, and psychotic symptoms were associated with poorer affective ToM scores. Disinhibition, loss of sympathy/empathy and hyperorality or altered food preferences were associated with cognitive ToM. All behaviours were significantly associated with poorer performance on ESCoT total score, but not the RME or SNQ.

Conclusion: The ESCoT was sensitive to social cognition impairments in people with aMCI/dementia and it relates to behaviour change in aMCI/dementia unlike established tests. Different subtests of the ESCoT were related to different behaviour changes. These findings suggest that the ESCoT may be a clinically valuable tool when examining social cognition.

Keywords: Edinburgh Social Cognition Test (ESCoT); social cognition, Theory of Mind, dementia, behavioural variant frontotemporal dementia (bvFTD); Alzheimer's disease; amnestic Mild Cognitive Impairment (MCI).

KEY POINTS

What is the key question this paper addresses: The aim of this study was to examine whether the Edinburgh Social Cognition Test (ESCoT) was sensitive to social cognitive impairments in people with amnestic Mild Cognitive Impairment (aMCI) and a range of neurodegenerative dementias and to explore associations between social cognition performance and behaviour changes. **What are the primary findings:** People with aMCI/dementia were impaired on the ESCoT and an established social cognition test, but only the ESCoT was sensitive to impairments in social abilities in people with aMCI/dementia with behaviour change. **What are the key scientific and practical implications of the findings:** The ESCoT is a valid measure of social cognition in people with aMCI/dementia and demonstrates associations with behaviour change. **What directions should be explored in future research:** Future studies using a longitudinal design could seek to examine whether social cognitive impairments precede behaviour change or vice versa, and differences in performance in individuals with different dementia subtypes.

INTRODUCTION

Social cognitive abilities are higher-order cognitive processes that allow individuals to interact with others in contextually specific situations and to respond appropriately in everyday interactions (Adolphs, 2009; Baez et al., 2016; Baez et al., 2012; Henry et al., 2015; Van Overwalle, 2009). They include emotion recognition, cognitive theory of mind (ToM; the ability to infer what someone might be thinking), affective ToM (the ability to infer how someone might be feeling), empathy, moral judgements and interpersonal (other) and intrapersonal (self) understanding of social norms, among others (Baez et al., 2016; Baez et al., 2013; Baksh et al., 2018; Kalbe et al., 2010; Love et al., 2015; Sebastian et al., 2011; Shamay-Tsoory et al., 2010).

People with neurodegenerative disease including dementia are often reported to have compromised social cognitive abilities (Abrahams, 2011; Bora et al., 2015; Bora & Yener, 2017; Christidi et al., 2018; Demichelis et al., 2020; Elamin et al., 2012; Kemp et al., 2012; Poletti et al., 2012). This is thought to underlie their inability to behave appropriately in social situations and build relationships with others (Brioschi Guevara et al., 2015; Gregory et al., 2002). Therefore, structured social cognition tests are extremely useful in clinical assessments in these populations (Henry et al., 2016). However, tests of social cognition are seldom included in clinical practice (Kelly et al., 2017a, 2017b). This may be due to a lack of tests that have been developed or validated in dementia (Spek et al., 2010), existing tests' associations with other cognitive abilities such as IQ (Baker et al., 2014), and their lengthy administration times (e.g., The Awareness of Social Inference Test; TASIT) (McDonald et al., 2003). Additionally, most social cognition tests suffer from their narrow scope (Kelly & McDonald,

2020), with few tests examining more than one or two abilities within the same test, thus limiting their representation of social abilities.

Mild Cognitive Impairment (MCI) exists along the continuum of normal aging to neurodegeneration (Petersen, 2004) and includes the prodromal stages to dementia (Vermunt et al., 2019), with amnestic MCI (aMCI; people with prominent memory impairments) showing high rates of conversion to Alzheimer's disease (AD). For instance, one study found that after 6 years, 93% of people with aMCI had converted to a definite diagnosis of AD (Mauri et al., 2012). Two aspects of social cognition that have been studied extensively are cognitive and affective ToM. Findings on impairments of ToM in aMCI are somewhat mixed within the literature. Some studies have shown no impairments in affective ToM using the Reading the Mind in the Eyes (RME) (Baglio et al., 2012) while others have found poorer performance compared to healthy controls (Eramudugolla et al., 2022; Rossetto et al., 2018) and more pronounced impairments in aMCI compared to non-amnestic MCI (Michaelian et al., 2019). These mixed results are also observed for cognitive ToM using false belief tests (Rossetto et al., 2020; Rossetto et al., 2018). A meta-analysis of general ToM abilities (where there was no distinction between cognitive and affective ToM) has found impairments in the medium effect sizes range compared to healthy controls (d = 0.63) (Bora & Yener, 2017). A second meta-analysis of both cognitive and affective ToM has found significant impairments compared to healthy controls, particularly on the RME (d = 1.22) and second order false belief tests (the protagonist's beliefs are different from the beliefs of other characters; d = 0.61) but not first order false belief tests (the protagonist's beliefs are different from the participants' belief; d = 0) (Yi et al., 2020). Longitudinally, some authors have observed that 46% of people with aMCI decline in their affective ToM ability over time and 28% decline in cognitive ToM

(Rossetto et al., 2022), suggesting that social cognitive impairments in ToM abilities are a common feature of those with aMCI (Michaelian et al., 2019).

In people with AD, the findings are inconsistent as to whether ToM is impaired, similar to the findings in people with aMCI. Some researchers have shown that people with AD are impaired on cognitive ToM (Yamaguchi et al., 2019) including false-belief tests (Cuerva et al., 2001; Fliss et al., 2016; Moreau et al., 2016). Yet, other studies have failed to find differences between AD and healthy controls (Koff et al., 2004). Studies utilising both first-order and second-order false-belief tests have shown that people with AD are impaired on second-order only (Fernandez-Duque et al., 2009; Gregory et al., 2002). In regards to affective ToM, while people with AD have been found to be impaired on the RME (Gregory et al., 2002; Yamaguchi et al., 2019), other studies have found intact affective ToM using the same test (Heitz et al., 2016; Koff et al., 2004; Moreau et al., 2016). Similar performance has been found between AD and healthy controls using the Faux Pas task (Gregory et al., 2002; Heitz et al., 2016) as well as the Social cognition & Emotional Assessment (mini-SEA), which assesses affective ToM and social norm understanding (Bertoux et al., 2016). However, a recent meta-analysis found that AD is associated with impairments in both cognitive ($g = 1.09$) and affective ToM ($g = 0.76$) (Demichelis et al., 2020).

In behavioural variant frontotemporal dementia (bvFTD), ToM impairments are more robustly found using an array of social cognition tests (Bora et al., 2015; Dodich et al., 2020; Poletti et al., 2012). Both cognitive and affective ToM are consistently and reliably impaired in people with bvFTD using tests such as the false-belief, RME and Faux Pas tests (Eslinger et al., 2007; Fernandez-Duque et al., 2009; Gleichgerrcht et al., 2011; Gregory et al., 2002; Lough et al., 2006; Snowden et al., 2001; Snowden et al., 2003; Torralva et al., 2007). On the RME,

people with bvFTD frequently attribute the wrong mental state to eye region expressions compared to healthy controls (Gregory et al., 2002; Lough et al., 2001; Lough et al., 2006; Modinos et al., 2009; Torralva et al., 2007). Newer tests of social cognition have also found impaired social cognition in people with bvFTD, such as the short version of TASIT (TASIT-S) (Kumfor et al., 2017). However, Fernandez-Duque et al. (2009) highlighted the importance of selecting appropriate tests when examining social cognition in people with bvFTD, as they showed intact performance for first-order false belief abilities, but impaired second-order false belief, as has been found in AD. In addition, while amyotrophic lateral sclerosis (ALS) primarily results in a loss of motor function, some patients demonstrate one or more features of FTD including impairments in behaviour features (i.e., ALS behavioural impairment) (Strong et al., 2017). A meta-analysis reported that social cognition deficits are central to the cognitive profile in ALS (Beeldman et al., 2016), including impairments in affective and cognitive ToM (e.g., Judgement of Preference) (Girardi et al., 2011; van der Hulst et al., 2014). Despite the somewhat mixed findings, overall, there is evidence to suggest that people with aMCI/dementia experience difficulties related to their ToM abilities.

Another social cognitive ability that is impaired in people with bvFTD is the understanding of social norms, where individuals act in a socially unacceptable manner and disregard social norms and rules (Rascovsky et al., 2011). In terms of intrapersonal understanding of social norms (i.e., how you should behave in a social interaction), the results are mixed. In some studies, people with bvFTD perform poorer than healthy controls, but AD and bvFTD perform similarly (Possin et al., 2013). Other authors have failed to find a difference between bvFTD and healthy controls (Baez et al., 2014; Lough et al., 2006). O'Callaghan et al. (O'Callaghan et al., 2016) found that compliance to basic social norms

(fairness) can be maintained in bvFTD; however more complex normative behaviours (prosociality, punishment) that require integration of social contextual information are impaired. While there is some evidence to suggest that the frequency of negative social interactions is associated with higher risk of developing MCI (Wilson et al., 2015) and social inappropriateness has been previously reported in MCI (Mallo et al., 2018), research on interpersonal understanding of social norms is currently limited in people with aMCI, AD and bvFTD.

Changes in behaviour and personality are part of the diagnostic criteria for bvFTD and include disinhibition, apathy, a loss of sympathy or empathy for others, perseverative behaviours and hyperorality or altered food preferences (Rascovsky et al., 2011). While empathy is considered a social cognitive ability (Baez et al., 2013), it is also conceptualised as a behaviour and is a core clinical feature of bvFTD in terms of behaviour change exhibited in this dementia subtype (Piguet et al., 2011; Rascovsky et al., 2011). Therefore, for the purposes of the present study it was considered a behaviour. Behaviour changes found in bvFTD are also present in people with AD (Desmarais et al., 2018; Ossenkoppele et al., 2015) and a frontal variant AD has been recognized (Dubois et al., 2014). There is evidence to suggest that behaviour changes are similar in bvFTD and AD, for example, one study showed that people with AD and bvFTD exhibited impaired empathy compared to healthy controls (Dermody et al., 2016). However, other authors have shown qualitative differences between the types of behaviour changes found in bvFTD compared to AD. Qualitative thematic analysis using data collected from informants has demonstrated that themes present in people with bvFTD centre around loss of control, changes in personality and loss of initiation actions while common themes found in people with AD relate to reduced eating and/or lost weight,

avoiding cooking and a loss in confidence (De Icaza Valenzuela et al., 2021). Research examining behaviour change in MCI is limited, but some research has shown that in people with MCI, informants report various changes in behaviour including changes in motivation (Michaelian et al., 2019; Tsang et al., 2012).

Some authors have argued that changes in behaviour influence interpersonal judgement and social functioning of people with bvFTD (Lough et al., 2006; Piguet et al., 2011; Rascovsky et al., 2011). Behaviour changes as such socially inappropriate behaviours, inappropriateness of affect and disinhibition, which are frequently reported in AD and bvFTD (Desmarais et al., 2018), can impact the interpersonal relationships of the person and their family (Oyebode et al., 2013). However the cause of the behaviour changes seen in people with dementia and the subsequent difficulties in social relationships they experience as a consequence is currently poorly understood. Social cognitive abilities are critical for successful social interactions (Adolphs, 1999) and difficulties in ToM can be substantially more debilitating than traditionally assessed impairments in cognition (Henry et al., 2015). Therefore, it could be hypothesised that social cognitive difficulties may be implicated in some of the behaviour changes seen in people with dementia. While research has looked at empathy and ToM within the same study (Lough et al., 2006), to our knowledge, there is currently limited research on behaviour change and its relation to social cognition in people with aMCI and dementia. Shany-Ur et al. (2012) found correlations between performance on the TASIT and empathy, apathy, euphoria, and disinhibition in people AD and bvFTD. However, another study examining this relationship in AD found no relationship between performance on the TASIT and behaviour changes (Poveda et al., 2017). There is evidence to suggest that affective and cognitive empathy are associated with social cognition in bvFTD

but some results suggest no associations (Eslinger et al., 2011). Due to limited examination and differential findings using different tests, the relationship between behaviour changes and social cognition is currently unclear but warrant investigation to provide novel insights into behaviour changes in people with aMCI/dementia.

The recently developed Edinburgh Social Cognition Test (ESCoT) (Baksh et al., 2018) assesses cognitive and affective ToM and inter-and intrapersonal understanding of social norms in a single test. It is sensitive to age-related changes in social cognition (Baksh et al., 2018), not related to performance on measures of IQ (Baksh et al., 2018; Baksh, Abrahams, et al., 2020), dissociates from executive functions (Baksh, Bugeja, et al., 2020) in healthy aging and demonstrates good convergent validity with established tests of social cognition (Baksh et al., 2018; Baksh, Abrahams, et al., 2020). Additionally, previous studies have shown that the ESCoT is a sensitive test of social cognition in adults with Autism Spectrum Disorders (ASD) (Baksh, Abrahams, et al., 2020) and people with acquired brain injury (Poveda et al., 2021). Thus, the ESCoT may be a valuable test to investigate social cognition in healthy and clinical populations. The present study aimed to examine the utility of ESCoT in people with dementia and explore potential associations between behaviour change and social cognitive abilities. We hypothesised that people with aMCI/dementia would perform poorer on all tests of social cognition compared to controls. Based on limited available research, we hypothesised that cognitive and affective ToM would be negatively associated with behaviour changes associated with social interactions including disinhibition, apathy and a loss of empathy for others. There is currently no comparable research examining potential associations between understanding of social norms and behaviour changes. However, as people with bvFTD and AD can act inappropriately in social interactions, we predicted that interpersonal and

intrapersonal understanding would also be negatively associated with behaviour changes related to social interactions (disinhibition, apathy and a loss of empathy for others).

METHODS

Participants

Twenty-eight participants (11 males) were recruited through The Edinburgh Cognitive Diagnosis Audit Research and Treatment Register (ECog-DART), a research register linked to the regional inter-disciplinary tertiary referral early onset cognitive disorders clinic at the Anne Rowling Regenerative Neurology Clinic, University of Edinburgh. Diagnoses were made by the consultant neurologist SP heading the early onset dementia clinical service according to the current consensus criteria: 11 people were diagnosed with bvFTD (Rascovsky et al., 2011), 13 people with AD (Dubois et al., 2007) and 4 with aMCI (Albert et al., 2011). Diagnoses were aided by magnetic resonance imaging (MRI) brain and HMPAO-SPECT imaging; measures of cerebrospinal (CSF) total Tau, Phosphorylated Tau, and beta amyloid (Ab1-42); and/or disease-causing mutations identified following a neurodegenerative gene panel analysis. Performance on tests of social cognition used in this study were not considered during the diagnostic process.

Twenty-eight cognitively healthy controls were also recruited using online advertisement and through a research volunteer panel at the Psychology Department, University of Edinburgh. None of the controls had any self-reported history of neurological or psychiatric disorders based on the Wechsler Adult Intelligence Scale (WAIS-III) exclusion criteria (Wechsler, 1997). There was no statistically significant difference between people with aMCI/dementia and controls in age or sex. There was however a significant difference in

years of education, with controls having more years of full-time education than people with aMCI/dementia (see Table 1). The study was approved by the Scotland A Research Ethics Committee (12/SS/0196) and the Psychology Research Ethics Committee of the University of Edinburgh (161-1314). All participants gave their informed consent to take part in the study.

Insert Table 1 around here

Materials

The Edinburgh Social Cognition Test (ESCoT) (Baksh et al., 2018). The ESCoT consists of 11 separate trials of different animated cartoon-style social interactions (1 practice). Each video was approximately 30 seconds long and after each, participants were asked four questions about what they saw. Questions were related to the social cognitive domains of cognitive ToM, affective ToM, interpersonal understanding of social norms and intrapersonal understanding of social norms. Participant responses were scored based on the quality of their answer with maximum points awarded to those that successfully extracted and integrated the relevant contextual information from the social interaction. Each question was scored out of 3, resulting in a score of 12 points for each social interaction and a maximum of 30 points for each subtest of the ESCoT. Participants could score a maximum total score of 120 points and higher scores indicated better performance. Previous work has demonstrated that the ESCoT has an intraclass correlation of 0.90 and internal consistency of 0.70 (Baksh et al., 2018).

Reading the Mind in the Eyes (RME) (Baron-Cohen et al., 2001). The RME was administered to assess affective ToM. Participants were presented with photographs of the eye region of human faces and participants were required to select one of four adjectives to

best describe what the person was thinking or feeling. Maximum score is 36 and higher scores indicated better performance. The RME has been shown to have an intraclass correlation of 0.83 and internal consistency of 0.61 (Vellante et al., 2013).

The Social Norms Questionnaire (SNQ) (Rankin, 2008): The SNQ assesses understanding of social norms. It consists of a list of behaviours and asked participants to indicate whether or not the behaviours were socially acceptable in the presence of a stranger or acquaintance. Maximum Total Score is 22, with higher scores indicated better performance. Validation data for the SNQ is lacking, however a recent study of a Dutch translation found an internal consistency of 0.59 and reliability of 0.64 (van den Berg et al., 2022).

Neuropsychological testing of people with aMCI/dementia. The neuropsychological tests were completed as part of routine clinical care and were administered by one of the authors SA. Premorbid IQ was assessed using the Test of Premorbid Functioning (TOPF) (Wechsler, 2011). The TOPF reliability ranges from 0.96-0.99, test-retest reliability of 0.89–0.95 and concurrent validity with the WAIS-IV Full Scale IQ (r = .70) (Holdnack & Whipple Drozdick, 2009). People with aMCI/dementia were then assessed on five cognitive domains (memory, executive function, fluency, language, and visuospatial function), see Table 2 for list of tests.

People with aMCI/dementia also completed the Edinburgh Cognitive and Behavioural Amyotrophic Lateral Sclerosis Screen (ECAS) (Niven et al., 2015), which is a brief cognitive and behavioural assessment routinely used at the dementia assessment service. While the ECAS was developed for people with Amyotrophic Lateral Sclerosis, it has been validated for use in

dementia (De Icaza Valenzuela et al., 2021; Saxon et al., 2020). The ECAS assessed memory, executive functions, fluency, language and visuospatial abilities. Participants could score a maximum of 136 points on the cognitive assessment, with a cut-off score of 105 or below suggestive of abnormal performance. Previous research has shown that the ECAS has an internal consistency of 0.75 (Abrahams et al., 2014).

The ECAS included a short informant-based behaviour semi-structured interview which measured behavioural domains listed as part of the bvFTD diagnostic criteria (Rascovsky et al., 2011). These behavioural domains included: disinhibition (e.g., impulsive, rash or careless actions), apathy or inertia (e.g., loss of interest, drive or motivation), loss of sympathy/empathy (e.g., diminished response to other people's needs and feelings), perseveration (e.g., complex, compulsive or ritualistic behaviours), hyperorality or altered food preferences (e.g., binge eating) and psychosis (e.g., has strange and/or bizarre beliefs and behaviours). A score of 1 indicated that behaviour change was present in that specific domain.

Statistical analysis

We examined group differences between people with aMCI/dementia and controls in performance on the subtests of the ESCoT (cognitive ToM, affective ToM, interpersonal and intrapersonal understanding of social norms) using a repeated measures analysis of covariance model (ANCOVA), adjusting for age, sex and years of education. While we matched people with aMCI/dementia to controls on age and sex, it was still necessary to control for the impact of these variables in the analysis (Pearce, 2016), particularly as previous studies found that age, sex and years of education were associated with ESCoT performance (Baksh

et al., 2018; Baksh, Abrahams, et al., 2020; Baksh, Bugeja, et al., 2020). We examined interactions between the groups (people with aMCI/dementia and controls), ToM (cognitive ToM, affective ToM) and social norms (interpersonal and intrapersonal understanding of social norms) in the ANCOVA model. Univariate models adjusting for age, sex and years of education were used to investigate group differences for the ESCoT total score, the RME and the SNQ.

In order to examine the associations between performance on the tests of social cognition and behaviour changes in people with aMCI/dementia compared to the controls, we fitted separate linear regression models for each of the ECAS behaviour changes (disinhibition, apathy or inertia, loss of sympathy or empathy, perseveration, hyperorality or altered food preferences and psychosis), with performance on the subtests of the ESCoT, ESCoT total score, the RME and SNQ as the outcomes. Each regression for the ECAS behaviour changes consisted of a group variable (controls, people with aMCI/dementia and behaviour change and people with aMCI/dementia without behaviour change), with age, sex and years of education fitted as covariates in the models. Outcome variables in the regression models were log transformed to avoid violation of normality and then back transformed for reporting. Significant associations from the ESCoT subtests analysis were presented using partial correlation graphs to visually illustrate the relationship between behaviour changes and performance on these subtests of social cognition. In accordance with requests from reviewers, we conducted exploratory analysis in people with aMCI/dementia to examine the relationship between performance on tests of cognition and tests of social cognition. In this analysis, we conducted partial correlations between the ECAS and tests of social cognition controlling for age and sex in the aMCI/dementia group only. The ECAS was chosen as it

covered the five domains assessed within a single test (memory, executive function, fluency, language, and visuospatial function). Years of education was not included in this analysis since there were missing data for this variable and our sample size was limited (n = 28). We also examined potential differences in social cognitive performance between people with bvFTD compared to people with AD. In the analysis of group differences in performance on tests of social cognition between people with dementia and controls, we used the false discovery rate (FDR) correction to correct for multiple comparisons as this area of research is well established. However, there is currently limited research directly examining the associations between social cognition and behaviour changes in people with dementia. Therefore, we were liberal in these analyses and did not correct for multiple comparisons, following the approach suggested by Rothman (Rothman, 1990). These analyses were exploratory in nature, with the aim of gathering initial insights and informing further investigations. Consequently adjusting for multiple comparisons could unnecessarily restrict the discovery of interesting patterns or associations (Gelman & Loken, 2013). All data analyses were conducted in SPSS (version 27) and R version 4.1.3 (R Core Team, 2022).

Transparency and Openness

The present study and its investigators adhered to the highest level of TOP guidelines in conducting and reporting the results. The study design and its analysis were not preregistered. Data used in the study may be made available upon reasonable request to the corresponding author.

Results

Table 2 shows the performance of people with aMCI/dementia on the tests of cognition and Figure 1 demonstrates the performance of people with aMCI/dementia and controls on the tests of social cognition (see supplementary materials Table S1 and Figure S2 for further details on performance including a breakdown of performance by diagnosis).

Insert Table 2 and Figure 1 around here

Social cognitive differences between people with aMCI/*dementia and controls*

We found a significant three-way interaction between ToM scores, social norm understanding scores and group ($F(1, 46) = 4.44$, $p = 0.04$, $\eta_p^2 = 0.09$). Post-hoc analysis adjusted for multiple comparisons showed that controls performed significantly better than people with aMCI/dementia on affective ToM ($t(53) = 5.08$, $p < 0.001$, Cohen's $d = 3.91$) only. Group differences for cognitive ToM ($t(38) = 1.90$, $p = 0.08$, Cohen's $d = 3.21$) and interpersonal understanding of social norms performance ($t(53) = 2.06$, $p = 0.06$, Cohen's $d = 3.99$) approached statistical significance after adjusting for multiple comparisons, but not for intrapersonal understanding of social norms ($t(53) = 0.81$, $p = 0.47$, Cohen's $d = 3.02$). Participants showed better performance on affective ToM compared to cognitive ToM ($t(54) = -2.66$, $p = 0.02$, Cohen's $d = 4.31$) and interpersonal understanding of social norms ($t(54) = 2.95$, $p = 0.009$, Cohen's $d = 4.66$) but not compared to intrapersonal understanding of social norms ($t(54) = -3.33$, $p = 0.004$, Cohen's $d = 4.65$). They also demonstrated better performance on intrapersonal understanding of social norms compared to cognitive ToM ($t(54) = -7.39$, $p < 0.001$, Cohen's $d = 3.65$) and interpersonal USN ($t(54) = -7.28$, $p < 0.001$, Cohen's $d = 4.02$). There was no difference between scores on cognitive ToM and interpersonal USN ($t(54) = 0.60$, $p = 0.55$, Cohen's $d = 3.81$).

We also found that controls showed significantly better performance than people with aMCI/dementia on the ESCoT total score ($F(1, 46) = 5.82$, $p = 0.02$, $\eta_p^2 = 0.11$) and the RME ($F(1, 44) = 6.05$, $p = 0.02$, $\eta_p^2 = 0.12$) but not the SNQ ($F(1, 44) = 2.05$, $p = 0.16$, $\eta_p^2 = 0.05$).

Associations between social cognition and behaviour change

Insert Figure 2 around here

Figure 2 demonstrates the percentage of people with aMCI/dementia exhibiting behaviour changes measured by the ECAS. Behaviour change was common in our sample with more than 25% exhibiting at least one behaviour change. The most prevalent behaviour changes were apathy or inertia and perseveration. This was followed by disinhibition and loss of sympathy or empathy, hyperorality or altered food preferences and finally symptoms associated with psychosis.

Poorer performance on affective ToM was found in people with aMCI/dementia who displayed apathetic behaviours ($\exp(\beta) = 0.82$, 95% confidence intervals (CI) = 0.69 - 0.97, $p = 0.03$), exhibited a loss of sympathy or empathy compared to controls ($\exp(\beta) = 0.78$, 95% CI = 0.64 - 0.94, $p = 0.01$), those with perseveration difficulties ($\exp(\beta) = 0.83$, 95% CI = 0.70 - 0.99, $p = 0.03$) and people with aMCI/dementia who presented with symptoms related to psychosis ($\exp(\beta) = 0.69$, 95% CI = 0.55 - 0.87, $p < 0.01$). People with aMCI/dementia who did not present with hyperorality or altered food preferences performed poorer than controls ($\exp(\beta) = 0.83$, 95% CI = 0.70 - 0.98, $p = 0.03$).

On interpersonal understanding of social norms, people with aMCI/dementia who presented with a loss of sympathy or empathy performed poorer than controls ($\exp(\beta) = 0.75$,

95% CI = 0.64 - 0.87, p < 0.001). People with aMCI/dementia who showed hyperorality or altered food preferences also performed poorer than controls (exp(β) = 0.73, 95% CI = 0.60 - 0.88, p < 0.01). The overall regression models for disinhibition, apathy, perseveration and psychosis were not statistically significant (p = 0.05, p = 0.18, p = 0.09 and p = 0.12 respectively). However those who exhibited disinhibition (exp(β) =0.79, 95% CI = 0.67 - 0.92, p < 0.01), apathy (exp(β) = 0.83, 95% CI = 0.71 - 0.97, p = 0.02), perseveration (exp(β) = 0.82, 95% CI = 0.70 - 0.95, p = 0.01) and symptoms related to psychosis (exp(β) = 0.76, 95% CI = 0.61 - 0.95, p = 0.02) performed poorer than controls, suggesting that these models were potentially underpowered due to a small sample size.

The overall models examining associations between cognitive ToM performance and behaviour changes, while adjusting for age, sex and years of education were not statistically significant (all p > 0.05). However, the variables relating to behaviour changes were significantly associated with poorer cognitive ToM performance, suggesting that these models were potentially underpowered. On this ToM measure, people with aMCI/dementia who exhibited disinhibition performed poorer than controls (overall model p = 0.07, exp(β) = 0.84, 95% CI = 0.72 - 0.98, p = 0.02) as did those who exhibited a loss of sympathy or empathy (overall model p = 0.12, exp(β) = 0.85, 95% CI = 0.73 - 0.99, p = 0.04) and those who showed hyperorality or altered food preferences (overall model p = 0.05, exp(β) = 0.80, 95% CI = 0.67 - 0.96, p = 0.02). All regression models examining associations between intrapersonal understanding of social norms performance and behaviour changes were not statistically significant (all p > 0.05). Full model statistics for all ESCoT subtest regression models can be found in the supplementary file Tables S3A – S3D.

Insert Figure 3 around here

Figure 3 shows partial regression plots displaying the relationship between ESCoT subtest performance and behaviour changes from the multiple linear regression models, while holding the other predictor variables constant. These figures demonstrate that, in people with aMCI/dementia who displayed specific behaviour changes, there was a significant negative relationship with performance on cognitive, ToM, affective ToM and interpersonal understanding of social norms while adjusting for age, sex and years of education.

Insert Table 3 around here

Table 3 shows the results of the linear regression models examining associations between ESCoT total scores and ECAS behaviour changes. In people with aMCI/dementia, exhibiting changes in all behavioural domains were associated with poorer performance on the ESCoT total scores compared to controls. There were no significant associations between people with aMCI/dementia without behaviour changes compared to controls on ESCoT performance, except for those without symptoms related to psychosis, which was associated with poorer performance. The models exploring potential associations between behaviour change and performance on the RME were not statistically significant (all $p > 0.05$). Moreover, there were no significant associations between the SNQ and behavioural changes (all $p > 0.05$). The full results for RME and SNQ models can be found in the supplementary file Tables S4A and S4B.

Exploratory analysis in people with aMCI/*dementia*

Partial correlations adjusting for age and sex (Table S5 in the supplementary file) between ECAS and tests of social cognition in people with aMCI/dementia showed significant positive

correlations between affective ToM and ECAS language, interpersonal understanding of social norms and ECAS executive functions and ECAS total score, ESCoT total score and ECAS executive functions and the RME and ECAS total score. Performance on the SNQ was significantly positively correlated with performance on ECAS language, verbal fluency, executive functions and ECAS total score.

Table S6 (in supplementary file) presents exploratory comparisons between people with bvFTD and AD on the tests of social cognition. There were no statistically significant differences between the two dementia groups (all $p > 0.05$).

DISCUSSION

People with neurodegenerative disease often exhibit declines in social abilities and behaviour (Christidi et al., 2018; Elamin et al., 2012); this is particularly true in people with a diagnosis of dementia (Bora et al., 2015; Gregory et al., 2002; Poletti et al., 2012). There is evidence to suggest that the ESCoT may be sensitive to impairments in social cognition in clinical populations (Baksh, Abrahams, et al., 2020; Poveda et al., 2021). Here we found that people with aMCI/dementia were impaired on affective ToM, ESCoT total score and the RME. Not only was the ESCoT sensitive to impairment in the aMCI/dementia group, but we found that poorer performance on the total ESCoT score was associated with exhibiting changes in all behavioural domains which form part of the bvFTD diagnostic criteria (Rascovsky et al., 2011), while differential associations between specific behaviour changes and subtests of the ESCoT were observed. On the standard measures of social cognition (RME and SNQ) there was no association between performance and behaviour change.

We found impairments in affective ToM using the ESCoT, which is in line with previous studies examining social cognition in people with aMCI/dementia (Bora et al., 2015; Bora & Yener, 2017; Demichelis et al., 2020; Dodich et al., 2020; Kessels et al., 2020; Poletti et al., 2012). In particular, we replicated impairments on the RME as others have shown (Gregory et al., 2002; Lough et al., 2001; Lough et al., 2006; Modinos et al., 2009; Torralva et al., 2007). Our finding suggests that the ability to infer what someone is feeling in a social interaction is compromised in aMCI/dementia. Consequently, this affective ToM difficulty could potentially limit the ability to engage in long term meaningful relationships and limit a person's social networks. Indeed, previous work has shown that impairments in affective ToM result in limited interpersonal relationships (Henry et al., 2015).

We found that the difference between controls and people with aMCI/dementia was no longer significant after adjusting for multiple comparisons on interpersonal (other) social norms. However, interpersonal skills are not routinely examined in relation to social norm understanding, therefore further research is needed to better understand the ability to recognise if someone behaved as others should behave in social interactions in people with aMCI/dementia. We also found no significant difference in intrapersonal understanding of social norms between groups on the ESCoT. This area of research is under investigated in the literature with only a handful of studies and mixed findings (Baez et al., 2014; Lough et al., 2006; O'Callaghan et al., 2016; Possin et al., 2013). However, these results are consistent with previous work showing that intrapersonal skills are not affected in healthy aging (Baksh et al., 2018) or adults with ASD (Baksh, Abrahams, et al., 2020). Based on our results, there is evidence to suggest that people with aMCI/dementia may understand how they themselves

might need to behave in social interactions, but it is currently unclear whether they are able to apply this understanding to interactions of another person.

Similar to previous studies (Desmarais et al., 2018; Ossenkoppele et al., 2015; Poveda et al., 2017), we found that behaviour changes were highly prevalent in our sample, with 70% exhibiting apathy or inertia, 65% having perseveration difficulties, 48% experiencing loss of sympathy or empathy and disinhibition, 30% showing hyperorality or altered food preferences and 26% having symptoms related to psychosis. Although we included a heterogeneous sample of people with aMCI/dementia, 39% of participants had bvFTD only and the findings show that some symptoms may be prevalent across aMCI/dementia, namely apathy, perseveration and hyperorality and altered food preference. Apathy in particular has been found to be prevalent in people with dementia (Radakovic et al., 2021). These findings emphasise the importance of measuring behaviour change in people with aMCI/dementia alongside traditional neuropsychological testing.

Studies examining the associations between behaviour changes and social cognition in people with dementia are distinctly lacking in the literature. In the present study we found that specific social cognitive processes were related to particular abnormal behaviours. Notably, lower scores on affective ToM were related to increased apathy, loss of sympathy or empathy, perseverative and symptoms of psychosis. People with aMCI/dementia who did not present with hyperorality or altered food preferences performed poorer than healthy controls on affective ToM. Lower scores on cognitive ToM were related to disinhibition, loss of sympathy or empathy and a change in eating behaviour. This is the first study to demonstrate a differential relationship between ToM and behaviour changes and suggests that ToM abilities may help to explain certain behavioural difficulties found in people with

aMCI/dementia. These preliminary results highlight a cognitive–behavioural conceptual link between affective ToM and empathy. This suggests that understanding the feelings of another is needed for empathic behaviours in people with aMCI/dementia; a link supported by neuroimaging research. The ventromedial prefrontal region is important for perspective-taking, which is an important process in social cognition (Shamay-Tsoory, 2011), and people with lesions localised to the ventromedial regions are significantly impaired on tests of affective ToM (Shamay-Tsoory et al., 2006). Relatedly, damage to the ventromedial prefrontal region results in impaired empathy (Beadle et al., 2018) and this region is commonly impaired in bvFTD and AD patients with behavioural variants (Bertoux et al., 2013; Woodward et al., 2015). Research shows that people with dementia and behaviour changes struggle with interpersonal relationships (Oyebode et al., 2013). Here we have shown aspects of social cognition may underlie this difficulty and that there is benefit in examining different aspects of social cognition separately, since the clinical profile of impairments may be different depending on the exhibited behaviour change. In regard to people with aMCI/dementia and no change in eating behaviour having poorer affective ToM ability, this was a somewhat surprising result with no clear explanation why this might be currently. It may be a spurious finding and further research in a larger sample is needed to replicate this finding to better understand how hyperorality or altered food preferences might be associated with ToM abilities.

The lack of significant associations between the RME and behaviour changes suggest that perhaps the ESCoT is a more sensitive test to measure specific behaviour changes. While the RME is considered an affective ToM test (Cuerva et al., 2001), it does assess aspects of cognitive ToM. Moreover, the focusing on the eye region, and attributing contrived

descriptors is limited in assessing processes in a naturalistic manner. Potentially, this may make it a less clear measure of affective ToM and could explain the null findings in comparison to the ESCoT which measured affective and cognitive ToM separately and using a more ecologically valid approach. There was consistency in our results in terms of associations between intrapersonal social norm understanding and behaviour change, as performance on both the SNQ and intrapersonal understanding of social norms subtest of the ESCoT were not associated with behaviour change. This would suggest that people with aMCI/dementia who present with behaviour changes may still retain their ability to process how they should behave in some social interactions. Similarly, patients with frontal lobe lesions are often described as knowing what is acceptable and what is unacceptable but not employing this knowledge to their behaviour (Beer et al., 2006; Stuss, 1991). Akin to group comparisons between people with aMCI/dementia and controls, intrapersonal understanding of social norms and its association with behaviour change is understudied in the literature. Therefore, further studies are needed to better understand this ability, particularly considering people engaging in inappropriate social behaviours is a hallmark characteristic of dementias with behavioural aspects (Ossenkoppele et al., 2015; Rascovsky et al., 2011). Social cognition can play an important role in the clinical care in dementia (Elamin et al., 2012) by identifying people who may need extra post-diagnostic support. These results provide evidence for the clinical usefulness of the ESCoT in detecting impairments in social cognition in people with aMCI/dementia, especially in those experiencing behaviour change.

There are advantages of the ESCoT for clinicians interested in assessing social cognition in people with MCI or dementia. Firstly, it has a short administration time (20-25 minutes) and there is evidence to suggest that it is a useful test of social cognition in clinical

populations (Baksh, Abrahams, et al., 2020; Poveda et al., 2021). Moreover, an improvement of the ESCoT compared to traditional tests of social cognition is its wider scope, as it assesses four domains of social cognition within one test. It assesses both cognitive and affective ToM, which until recently, were not considered separate domains (Sebastian et al., 2011) or relied on different tests to assess them separately, making direct comparisons between domains difficult. The ESCoT also allows clinicians to assess interpersonal and intrapersonal understanding of social norms, which is not commonly measured. This important feature can provide clinicians with a more representative assessment of a person's social abilities and addresses a previously highlighted issue in the literature (Kelly & McDonald, 2020). One limitation however of the ESCoT is that it does not assess emotion recognition, which is arguably the most studied aspect of social cognition in dementia. Therefore, future work might examine the relationship between emotion recognition and changes in behaviour in aMCI and dementia using different social cognitive tests. Nonetheless, our results highlight the value of measuring social cognition more generally in clinical settings. Such assessments could be used as an adjunct to routine cognitive screening tests for diagnosis and monitoring of disease progression. Impaired social cognition has implications for care and caregiver burden (Brioschi Guevara et al., 2015) and therefore should be identified early and accurately. Finally, given the sensitivity of the ESCoT from previous work and the current study in detecting social cognitive impairments, it could potentially be used as a secondary outcome measure in clinical trials of dementia as social cognition is not assessed in such settings, but is nevertheless an important ability to examine (Henry et al., 2016).

We recognise certain limitations in the present study. Firstly, our sample consisted of a 'real world' and, therefore, heterogeneous group of people including those with AD, bvFTD

and included a small number with aMCI. Research shows that these groups all show social cognition impairments (Bora et al., 2015; Bora & Yener, 2017; Demichelis et al., 2020; Dodich et al., 2020; Kessels et al., 2020), and our findings show that the ESCoT may be useful to apply in dementia clinics during assessment prior to final diagnosis and be used to help explain behaviour change. We conducted exploratory analysis examining potential differences in performance between people with bvFTD and AD which did not show significant differences; however our sample sizes were small. Therefore, future studies would benefit from examining social cognition using the ESCoT in a larger population of different subtypes of dementia to examine how distinct profiles are affected and determine whether the test may be useful in a diagnostic setting. We found significant correlations between ECAS domains and tests of social cognition in people with aMCI/dementia, but the interpretation of these results is currently limited given the heterogeneity of our group. Additionally, the focus of our study was on early onset dementia, therefore these results should be replicated in older adults with dementia. Some of the results indicated that the study may have been underpowered. While we did not find a statistically significant difference in cognitive ToM between the groups, the results were trending towards significance. Given our sample size of 56 participants, it is possible that our analysis may have been underpowered to detect a difference in performance, this is supported by the large Cohen's *d* in the post-hoc analysis. Therefore, it may be premature to conclude that cognitive ToM abilities do not differ across groups when assessed using the ESCoT, as others have suggested using different social cognition tests (Gregory et al., 2002; Koff et al., 2004). Future studies should include a larger sample size before conclusions can be made about this social cognitive ability in people with dementia. Another limitation was that we did not collect cognitive data in our control group. While participants were asked to self-report any history of neurological or psychiatric

disorders based on the WAIS exclusion criteria, objective testing would have allowed us to confirm this and examine the relationship between cognition and social cognition within this group compared to people with aMCI/dementia. Previous studies have examined the relationship between executive functions and ESCoT performance in healthy participants (Baksh, Bugeja, et al., 2020) but such findings would benefit from replication to examine their robustness. Finally, given the exploratory nature, limited sample size and the lack of literature examining the relationship between social cognition and behaviour change, we did not correct for multiple corrections in this analysis to avoid being conservative in our interpretation of the results. Our aim for this analysis was to gather novel insights into behaviour changes and associations with social cognition and to encourage investigation in this currently neglected area of research. Therefore some caution should be taken when interpreting our results and future studies should attempt to replicate our findings to better understand how social cognition might impact behaviour changes seen in people with aMCI or dementia.

In regard to future directions, there is evidence to suggest that some tests of social cognition can distinguish dementia from major psychiatric disorders and developmental disorders by showing differential performance and profiles based on the condition (Cotter et al., 2018; Gossink et al., 2018). Considering previous work in adults with ASD (Baksh, Abrahams, et al., 2020) and the current findings, it would be of interest to examine whether the ESCoT could be useful for this purpose in clinical settings. Additionally, it is currently unclear which occurs first, social cognitive impairment or behaviour change. Therefore, future studies using a longitudinal design could seek to examine the order in which they occur to provide a better understanding of such changes in people with MCI or dementia. Future

studies may also seek to investigate how the ESCoT and subtests correlate with imaging and pathology data to understand localisation of impairments in performance.

Given the prevalence of social cognition deficits in people with aMCI or dementia and that existing tests of social cognition are limited in their clinical usefulness, and the relationship shown here between the ESCoT and behaviour changes, it may be a helpful addition to a comprehensive neuropsychological assessment (Henry et al., 2015). This may help identify why a person is experiencing some behaviour changes, be useful to educate both the person, their families and clinicians or ways to manage this behaviour. The present study provides evidence for the application of the ESCoT in clinical settings to examine social cognitive abilities in people with aMCI or dementia. It also demonstrates that the ESCoT is sensitive to social cognitive impairments in those who exhibit behaviour changes.

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Conflict of Interest

The authors declare that they do not have any conflict of interest.

Author contribution

R. Asaad Baksh played a lead role in conceptualization, investigation, project administration, formal analysis, data curation, software, visualization, writing of original draft and writing of review and editing, supporting role in resources and lead role in funding acquisition, methodology and validation. Sarah E. MacPherson played a lead role in supervision, supporting role in project administration and writing of review and editing and equal role in conceptualization, methodology. Bonnie Auyeung a played a supporting role in supervision, supporting role in project administration and writing of review and editing and equal role in conceptualization, methodology. Suvankar Pal played a supporting role in project administration and writing of review and editing and methodology. Sharon Abrahams played a lead role in conceptualization, supervision, supporting role in project administration and writing of review and editing and equal role in methodology.

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Table 1. Demographics of people with aMCI/dementia and healthy controls: mean (SD) and frequencies

	aMCI/Dementia group	Controls	p value for comparison
n	28	28	-
Age	62.50 (5.96)	64.54 (7.35)	0.26
Sex (M:F)	18:10	11:17	0.11
Years of education	12.08 (2.23)	15.57 (2.59)	< 0.001

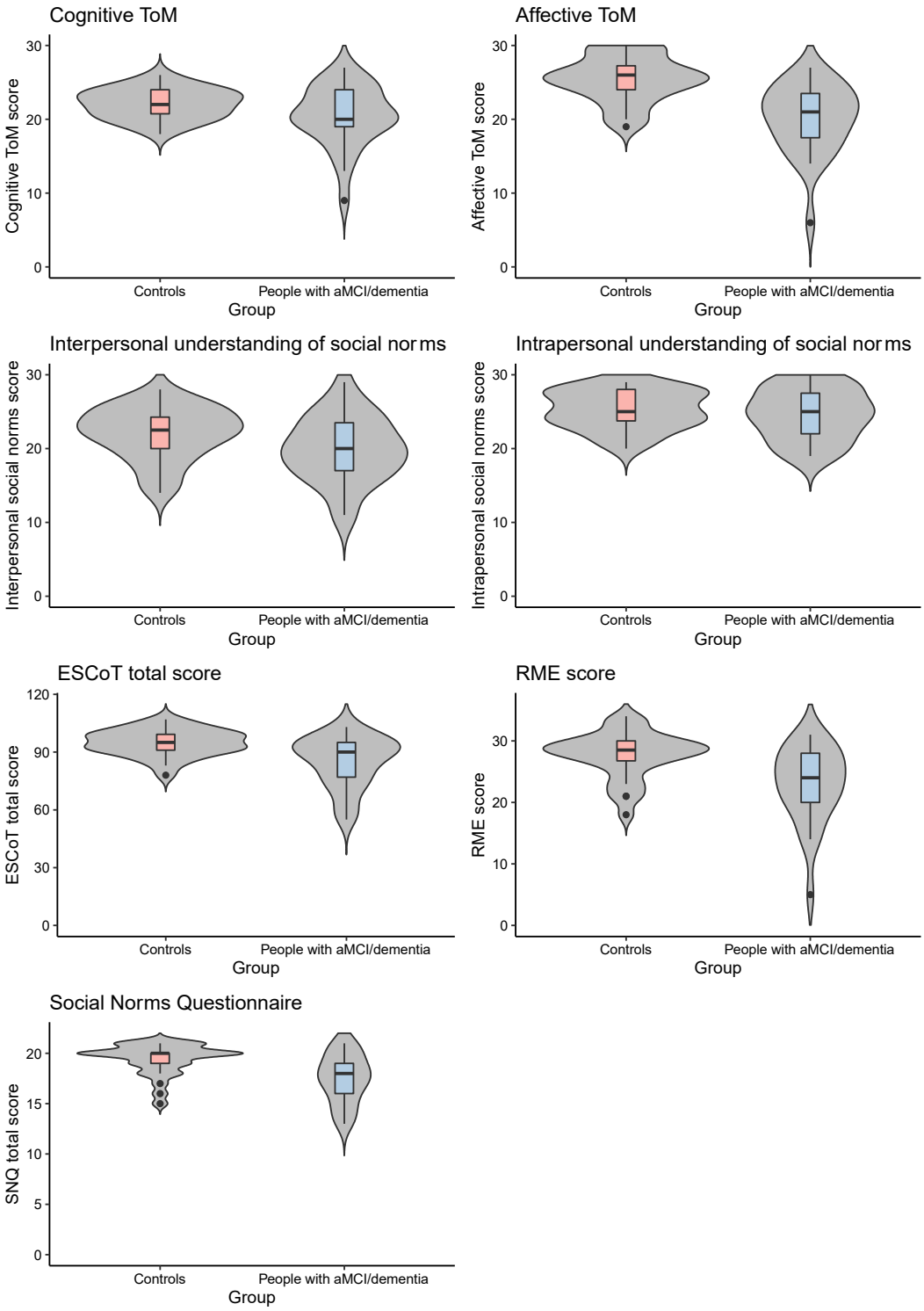
aMCI/d*ementia group's years of education n = 24.*

Table 2. Performance of people with aMCI/dementia on the tests of cognition

Tests of cognition	Maximum score	n	Mean (SD)
ECAS			
Language	28	28	23.32 (5.05)
Verbal fluency	24	28	11.32 (7.58)
Executive functions	48	28	26.46 (10.22)
Memory	24	28	7.96 (6.06)
Visuospatial skills	12	28	10.71 (1.84)
ECAS total score	136	28	80.61 (22.47)
Memory			
BMIPB – story recall			
Immediate recall	60	27	12.11 (7.37)
Delay recall	60	27	9.33 (8.09)
% retained	100	27	66.81 (42.82)
BMIPB – figure recall			
Copy	80	26	73.08 (9.91)
Immediate recall	80	27	36.22 (18.60)
Delayed recall	80	26	32.46 (20.25)
% retained	100	26	80.00 (24.82)
Free and Cued Selective Reminding Test (FCSRT)			
Free recall	48	26	13.35 (7.35)
Cued recall	48	26	38.88 (9.05)
Sensitivity to cuing (%)	100	25	78.20 (19.34)
Delay	16	23	3.83 (3.16)
Cued	16	23	13.04 (3.36)
Executive functions			
Trail Making Test (seconds)			
Part A	NA	26	49.42 (21.53)
Part B	NA	21	123.95 (69.69)
D-KEFS card sorting (scaled score)	20	26	7.85 (2.77)
Fluency			
FAS Total score	NA	27	26.59 (16.51)
Animal fluency score	NA	25	13.36 (4.53)
Language			
Graded naming test	30	27	16.11 (7.68)
Warrington spelling test	30	20	19.40 (8.28)
TROG	40	19	36.74 (13.68)
Visuospatial			
Dot counting	10	15	9.87 (0.35)
Number location	10	15	7.13 (3.18)

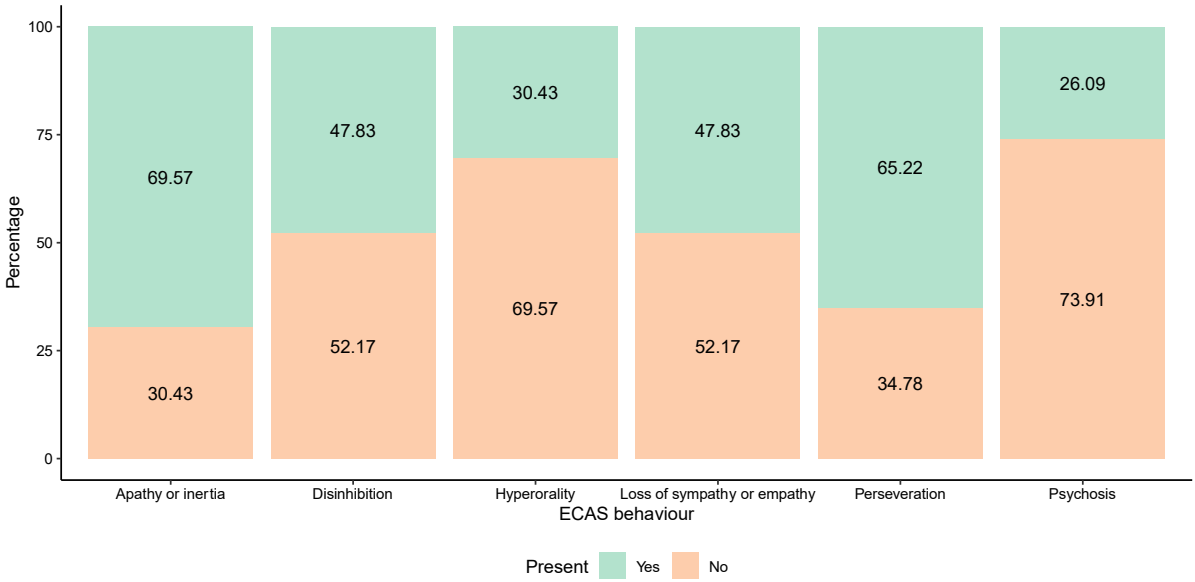
ECAS, Edinburgh Cognitive and Behavioural Amyotrophic Lateral Sclerosis Screen (Niven et al., 2015); BMIPB, BIRT Memory and Information Processing Battery (Coughlan et al., 2007); Trail Making Test (Reitan, 1955; Reitan & Wolfson, 1993); FSCRT, Free and selective cued reminding test; D-KEFS, Delis-Kaplan Executive Function System (Delis et al., 2001); letter fluency (Benton & Hamsher, 1989); Graded Naming test (McKenna & Warrington, 1983), the Warrington spelling test (Baxter & Warrington, 1994); TROG, Test for Reception of Grammar (Bishop, 2003). Visuospatial tests from the Visual Object and Space Perception Battery (VOSP) Battery (Warrington & James, 1991). NA not applicable as there is no maximum score.

Figure 1. Violin plots demonstrating performance of people with aMCI/dementia and controls on the tests of social cognition



ESCoT aMCI/dementia group n = 27. RME aMCI/dementia group n = 25. SNQ aMCI/dementia group n = 26. SNQ controls n = 27. ToM, Theory of Mind; RME, Reading the Mind in the Eyes; SNQ, Social Norms Questionnaire.

Figure 2. Percentage of people with aMCI/dementia who exhibited behaviour changes



ECAS Edinburgh Cognitive and Behavioural Amyotrophic Lateral Sclerosis Screen, n = 23.

Figure 3. Partial regression plots displaying the relationship between ESCoT subtest performance and behaviour changes

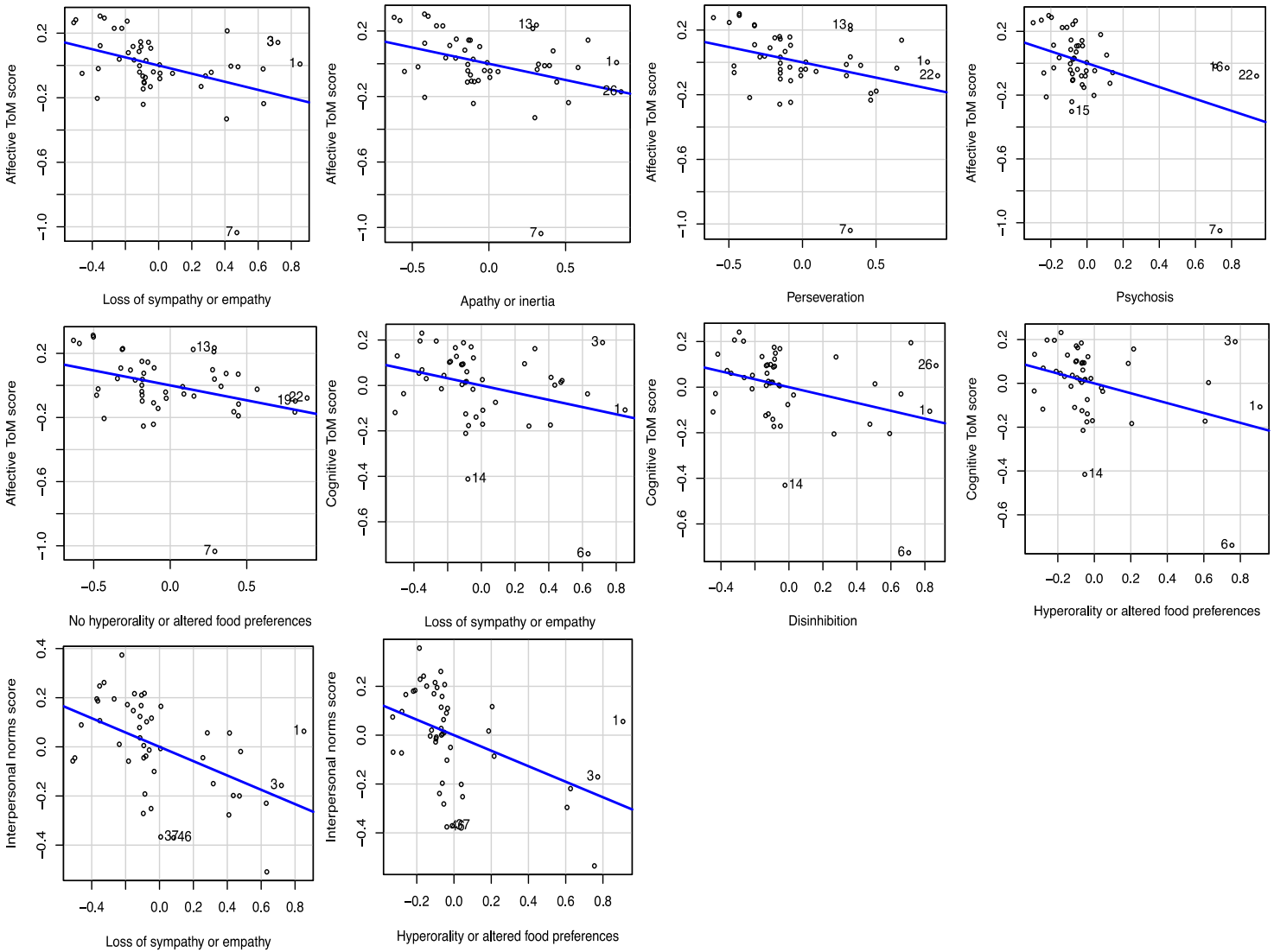


Table 3. Associations between behaviour change and performance on ESCoT total score

			ESCoT total score	
ECAS behaviour change	Model statistics		exp(β) (95% CI)	p value
Adjusted for age, sex and years of education				
Disinhibition	R^2 = 0.37, *F*(5, 41) = 4.77, p = 0.002	Yes	0.87 (0.78 - 0.96)	0.007
		No	0.92 (0.84 - 1.02)	0.12
Apathy or inertia	R^2 = 0.36, *F*(5, 41) = 4.60, DF, p = 0.002	Yes	0.88 (0.80 - 0.97)	0.009
		No	0.93 (0.83 - 1.04)	0.79
Loss of sympathy or empathy	R^2 = 0.41, *F*(5, 41) = 5.79, p = 0.0004	Yes	0.84 (0.76 - 0.93)	0.001
		No	0.94 (0.86 - 1.03)	0.18
Perseveration	R^2 = 0.35, *F*(5, 41) = 4.47, p = 0.002	Yes	0.88 (0.80 - 0.97)	0.01
		No	0.91 (0.82 - 1.02)	0.11
Hyperorality or altered food preferences	R^2 = 0.39, *F*(5, 41) = 5.17, p = 0.0009	Yes	0.84 (0.74 - 0.94)	0.004
		No	0.92 (0.84 - 1.01)	0.07

Psychosis	R^2 = 0.37, *F*(5, 41) = 4.90, p = 0.001	Yes	0.84 (0.74 - 0.96)	0.01
		No	0.91 (0.84 – 1.00)	0.047

ESCoT, Edinburgh Social Cognition Test. The reference group for the behaviour changes was controls. 95% CI; Confidence interval.