executive functioning, and whether patients with AD displayed impaired performance compared with normal elderly controls (NECs). We also wanted to examine whether the CET could adequately detect early impairments in patients who have MCI, thereby differentiating them from NECs. Patients with MCI often have mild memory impairments that closely resemble the impairments associated with AD, but are of a lesser severity (Chertkow, 2002). A nal aim of this study was to determine whether CET performance relied on executive functioning or whether other domains such as semantic ability were involved. This approach acknowledges the argument that any putative executive function task must, by de nition, involve the coordination of other cognitive processes (e.g., Miyake, Emerson, & Friedman, 2000). Previous studies suggest that the CET involves cognitive processes associated with calculation (Axelrod & Millis, 1994), semantics (Kopelman, 1991), executive functioning (Spreen & Strauss, 1998), and general intelligence abilities (Axelrod & Millis, 1994; Goldstein et al., 1996) insofar as these processes can be assessed using standard neuropsychological tests. On the basis of the literature outlined below, we hypothesized that semantic memory would be an important supra-ordinate domain to examine.

The CET was originally designed by Shallice and Evans (1978) to examine estimating abilities in patients with frontal lobe damage compared with patients with lesions outside frontal regions. Their 15-item assessment was a relatively simple test that was administered to patients. They were required to estimate answers to questions that had either a quantitative response (e.g., a numerical answer such as “45 mph” to the question: “How fast do race horses gallop?”) or a qualitative or nominative response (e.g., “couch” to the question: “What is the largest object normally found in a house?”). The authors calculated patients’ scores on the basis of a 4-point scale that was devised according to the responses given by the control group (*within the normal range*, *quite extreme*, *extreme*, and *very extreme*). Shallice and Evans found that patients with frontal lobe damage gave signi cantly more extreme answers on the CET relative to patients with localized damage in parietal regions. As such, they argued that the test encompassed executive functioning capacities. Although researchers have since replicated the results of Shallice and Evans regarding CET impairment in frontal lobe lesion patients (Shallice & Burgess, 1991; Smith & Milner, 1984), others such as Taylor and O’Carroll (1995) failed to replicate the original ndings. Taylor and O’Carroll compared CET performance in a wide range of patients with different forms of dementia and brain damage. They concluded that patients with alcoholic Korsakoff’s syndrome performed signi cantly worse than patients with frontal lobe lesions, as well as patients with closed head injuries. These authors did not suggest that any one speci c cognitive function was associated with performance on the CET. Rather, they suggested that future patient groups should consist of participants with more localized brain damage. Nonetheless, these results compelled researchers to question whether the CET encompasses executive functioning components alone or whether other cognitive domains such as semantic memory abilities are involved in task performance. Since the Taylor and O’Carroll study, the CET has been modi ed and used as a task to detect cognitive de cits in elderly participants (Gillespie, Evans, Gardener, & Bowen, 2002) and patients with Korsakoff’s syndrome (Brand et al., 2003; Kopelman, 1991) as well as other patients with brain damage (Goldstein et al., 1996; Mendez, Doss, & Cherrier, 1998).

In the Gillespie et al. study (2002) CET performance in NECs was dependent on semantic abilities related to verbal intelligence. Goldstein et al. (1996) examined the performance of AD patients and NECs using a version of the CET that required participants to provide both qualitative and quantitative responses. They found that AD patients produced more extreme responses on the CET compared with NECs. They concluded that this impairment was not related to word- nding de cits. Instead, they found that the task required cognitive processes related to accessing semantic information. They argued that adequate performance on a cognitive estimation test requires intact semantic memory to retrieve knowledge, facts, and rules associated with the questions and recommended that further tests involving cognitive estimation performance in AD patients should be compared with tasks involving semantic measures. In a manner, Mendez et al. (1998) compared performance on a different cognitive estimation test between AD patients and patients with frontotemporal dementia (FTD). They found that AD patients, who typically display marked impairments in episodic and semantic memory (Albert et al., 2001), performed worse than FTD patients, who typically display marked impairments on tasks involving executive functioning (Hodges et al., 1999; Perry & Hodges, 2000a). Mendez et al. (1998) therefore suggested that cognitive estimation encompasses semantic as well as executive functioning components.

Thus, previous research involving cognitive estimation has implied that several cognitive processes are necessary for adequate performance on this task. The cognitive pro le of AD is initially characterized by an amnestic syndrome particularly involving episodic and semantic memory (Chertkow, 1999; Lines et al., 1991; Tierney, Szalai, Dunn, Geslani, & McDowell, 2000). However, there is increasing awareness that AD patients can present with a heterogeneous pro le of cognitive de cits, with some cases presenting with predominant nonmemory impairment (e.g., visual disturbances, language impairment; for a brief review see Perry & Hodges, 1999). Relevant to our purposes, available evidence indicates that AD patients exhibit executive function de cits as the disease moves beyond the early amnestic phase (Perry & Hodges, 1999) and that some patients manifest impaired executive functioning abilities even at early stages of the disease (Albert et al., 2001; Binetti et al., 1996; Collette et al., 1999). From a clinical perspective, cognitive estimation might be a useful bedside measure to differentiate between NECs and those with very mild memory impairment or the early stages of AD. MCI patients perform worse than healthy NECs on neuropsychological tests of memory but do not meet the National Institute of Neurological and Communications Disorders and Stroke—Alzheimer’s Disease and Related Disorders (NINCDS–ADRDA) criteria for AD (Chertkow, 2002; Flicker, Ferris, & Reisberg, 1991; Petersen, 2000). By de nition, MCI patients display minimal impaired performance compared with NECs when tested on other cognitive domains (Flicker et al., 1991; Petersen, 2000; Petersen et al., 2001, 1999). However, given the evidence suggesting early executive function de cits in AD, we also wanted to determine whether CET performance in MCI patients would be impaired in comparison with NECs.

We also examined the relationship between CET performance and neuropsychological test scores to determine which cognitive

processes were most associated with the CET. We predicted that the CET encompasses cognitive factors associated with executive functioning. However, we also predicted that neuropsychological tasks involving semantic representation would be closely related to CET performance. In this case, we believed that AD patients (and possibly MCI patients) would display poor performance on the CET, because AD patients are impaired on neuropsychological tasks involving semantic representation and impaired executive functioning (Perry, Watson, & Hodges, 2000).

To do this, we made several modi cations to the CET. Previous versions included questions that required responses that were nonquantitative (e.g., "What is the best paid job in England?"). In our version, all questions required participants to give quantitative answers, unlike those of previous versions (Goldstein et al., 1996; Shallice & Evans, 1978). Furthermore, because our version of the CET is entirely quantitative, it is easier for clinicians to score and allows the use of standard deviation units to determine whether or not patients are signi cantly impaired when compared with a group of normal control subjects. Below, we rst describe a 23-item pilot version of the test used to gather normative responses and to identify which items to retain for the nal version of the test. The nal 15-item version of the CET was then administered to a new group of NEC participants and AD and MCI patients to evaluate group differences.

Method

Development and Standardization

A pilot version of the CET consisted of a total of 23 questions from previous versions of the CET (Axelrod & Millis, 1994; Shallice & Evans, 1978) and new items generated by the authors. These items were administered to 69 participants who had a mean age of 52 years (SD = 23 years), and a mean education level of 15.5 years (SD = 4.0 years). This sample consisted of individuals who were working at our research institute as well as a subsample of elderly participants from our research cohort who undergo routine neuropsychological testing to ensure that they are cognitively normal for their age group. For each question, participants were required to answer in numerical terms using units of measurement comfortable for them.

To devise a scoring method, we calculated the mean and standard deviation of the quantitative responses to each question from the normative group of 69 participants, with the mean representing the 50th percentile of the normal distribution curve. All values that fell within one standard deviation of the mean response were de ned within the 16th–84th percentiles and were assigned a deviation score of 0. Responses that were less than or greater than one standard deviation from the mean response were de ned within the 2nd–16th percentiles and the 84th–98th percentiles and were assigned a deviation score of 1. Finally, responses that were less than or greater than two standard deviations above and below the mean were de ned as greater than the 98th percentile or less than the 2nd percentile and were assigned a deviation score of 2.

The distribution curve for each individual question was assessed for normality. Eight of the 23 questions did not have normal distributions and were discarded from the nal test version. The 15 questions that had normal distributions and ranges were retained for the nal version of the test. Five of these were retained from the original test developed by Shallice and Evans (1978; Questions 1, 2, 4, 5 and 9 in our version) whereas the remaining 10 items were new to this version. The nal version of the CET, which can be found at http://dx.doi.org/10.1037/0894-4105.20.1.123.supp, was administered to all participants. Table 1 lists the values of responses that were given by the 69 participants who established the normative data for the test. With these results, we calculated a total score for each subject by summing the deviation scores from each of the 15 questions. A higher deviation score corresponded to more impaired performance. The mean CET score for the 69 participants who constituted the normative cohort was 5.61 (SD = 2.8).

Participants

The nal version of the CET was then administered to NEC, MCI, and AD participants. A new sample of 25 NEC participants were recruited from community volunteers as well as the Family Practice Clinic at the Jewish General Hospital in Montreal, Canada. A preliminary neuropsychological battery, clinical assessment, and neurological exam were carried out to verify that they were neurologically and cognitively unimpaired for their

Table 1
Normative Values of Answers Falling Within the Specific Percentile Ranges (Answered Metric Version) for all 15 Items on the CET in the Normative Sample (n = 69)

Question (unit of measurement)	< 2nd percentile	2nd–16th percentile	16th–84th percentile	84th–98th percentile	> 98th percentile
race horses (km/hr)	< 17	18–27	28–70	71–98	> 99
spine length (inches)	< 55	56–63	64–100	101–134	> 135
oldest age (years)	< 104.0	105–110	111–121	122–126.0	> 127
height woman (inches)	< 58	59–63	64–66	67–68	> 69
necktie length (inches)	< 20	20–26	26.0–48.0	48.1–59.7	> 59.7
weight elephant (lbs)	< 489	490–1000	1001–5000	5001–30480	> 30480
jet speed (km/hr)	< 240	241–480	481–1082	1083–2160	> 2161
temperature, Paris (°C)	< −14	−14 to −3	−2 to 10	11–19	> 20
TV programs	< 4	4–4.9	5–8.4	8.5–18.1	> 18.1
marathon time (hrs)	< 2	2.1–2.9	3.0–8.0	8.1–15.0	> 15.0
weight hammer (lbs)	< 0.75	0.76–1.5	1.5–5.1	5.2–12.8	> 12.9
shower water (L)	< 6	7–11.3	12–100	100–349	> 350
height giraffe (feet)	< 8	8–10	11–20	21–30	> 31
liquid consumption (L)	< 0.4	0.4–0.9	1.0–3.9	3.9–7.0	> 7.1
pyramid age (years)	< 500	501–1999	2000–5000	5001–6660	> 6660

Note. An answer that fell within the 16th–84th percentile was assigned a score of 0, an answer that fell within the 84th–98th percentiles was assigned a score of 1, and an answer that was given above the 98th percentile and below the 2nd percentile was assigned a score of 2. CET = cognitive estimations test.

age. An additional 15 NEC participants were recruited from the Department of Psychology at Concordia University and were screened with a neuropsychological test battery. These latter participants were administered a health-screening questionnaire to rule out the following factors: a history or presence of a signi cant medical, neurological, or psychiatric condition that could in uence cognitive performance; the presence of two or more risk factors for artherosclerosis (i.e., diabetes, hypertension, hyperlipidemia, or a 20 pack/year[1] history of cigarette smoking); medication use that could in uence cognitive status; vision that was not normal or corrected to normal; or English not being the participant's native language. Thus, the total sample of NECs consisted of 40 participants.

We also had the opportunity to examine the relationship between CET scores and performance on other neuropsychological tests through a parallel study on problem solving (transitive inference) in 39 older adults (Akerib & Phillips, 2002). These participants (31% men, 69% women) had a mean age of 73.8 years (SD = 7.6) and mean education of 13.8 years (SD = 3.3) and, thus, were comparable with the NECs reported above. This study included neuropsychological tests similar to those used in the Memory Clinic battery (i.e., CET, semantic uency, WAIS-III Similarities) and also examined performance on the Wisconsin Card Sorting Test (WCST). Because this second cohort was not speci cally recruited to be a control group for the clinical samples reported below, we shall refer to this group as normal elderly (NE). These participants were not used in the between-groups analyses of the clinical samples reported below; however, their data were used to examine the relationship between CET performance and other cognitive domains using hierarchical regression.

The MCI group consisted of 73 participants recruited from the McGill University Memory Clinic at the Jewish General Hospital. These participants were referred to the clinic on the basis of complaints of memory loss reported either by themselves or by their family members. The subjective memory complaints were accompanied by objective evidence of memory loss on mental status testing and usually supported by neuropsychological test scores that were at least 1 standard deviation below the normative values for their age (Petersen, 2000).[2] Memory performance among the MCI patients was not impaired enough to meet the NINCDS–ADRDA criteria for probable AD (McKhann et al., 1984), and there was no evidence of functional impairment as determined by the clinical assessment or by the Lawton Scale of Instrumental Activities of Daily Living.

The AD sample consisted of 40 participants who met the NINCDS–ADRDA (McKhann et al., 1984) criteria for the diagnosis of probable AD. These patients were evaluated at the McGill University–Jewish General Hospital Memory Clinic, a tertiary referral center where diagnoses are made by geriatricians and neurologists. All participants were mild to moderate in dementia severity, as classi ed according to the Washington University Clinical Dementia Rating Scale and met the criteria for "1.0" on that scale (Hughes, Berg, Danziger, Coben, & Martin, 1982). There was no evidence on clinical evaluation of systemic or other neurological disease suf cient to interfere with cognitive function. We excluded structural brain disease by CT and/or MRI and did blood work including CBC, routine chemistry, thyroid function, serum B12, folate, and VDRL (syphilis screen). All patients scored less than a 4 on the Hachinski ischemic scale (Hachinski et al., 1975). The Mini-Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975) was carried out by the clinician as a global assessment tool.

Table 2 shows the demographic descriptive features for the mean (SD) age, education, and MMSE scores for the entire sample of elderly controls and patients. A one-way analysis of variance (ANOVA) comparing age differences between the three groups (NEC, MCI, and AD) revealed a signi cant age effect, $F(2, 147) = 6.51, p < .002, \eta^2 = .081$. A post hoc analysis indicated that the AD group was signi cantly older than the NECs. A one-way ANOVA comparing education levels between the three groups revealed a signi cant effect of education, $F(2, 146) = 8.48, p < .001, \eta^2 = .104$. Post hoc analyses indicated that the AD group had lower education levels compared with the NEC group but that NEC and MCI groups did not differ. Finally, a one-way ANOVA revealed that there was a signi cant difference on MMSE scores, $F(2, 125) = 30.11, p < .0001, \eta^2 = .325$, across all three groups. Tukey's post hoc analyses revealed that, as expected, the AD patients had signi cantly lower MMSE scores than the MCI patients and NEC participants but that the MCIs and NECs did not differ.

Table 2
Demographic Results Means (SD) and MMSE Scores for NECs, MCI, and AD Patients

Measure	NEC	MCI	AD
Age (years)	74.1 (7.1)	74.0 (7.3)	78.8 (5.9)
Education (years)	13.8 (3.3)	12.7 (3.4)	10.7 (2.9)
MMSE (/30)	28.7 (1.2)	27.7 (1.9)	25.1 (2.6)

Note. MMSE = Mini-Mental State Examination; NECs = normal elderly controls; MCI = mild cognitive impairment; AD = Alzheimer's disease.

Although there were no signi cant correlations between education or age and performance on the CET, we adopted a conservative approach and used age and education as covariates for the CET and neuropsychological analyses reported below.

Procedure

CET administration. The CET was administered in conjunction with the neuropsychological battery in participants' homes or at the hospital or university in a quiet environment. All of the questions were read aloud and participants were instructed to give their best estimate when answering each question. Participants were explicitly told that there was no single correct response to the question, and they were encouraged to answer with their "best guess" or their "best estimation." If explicit units of measurement were not provided with the answer, participants were prompted to provide a unit of measurement (i.e., "would you say liters or gallons?").

Neuropsychological assessment. A series of neuropsychological tests was administered to determine the relationship between other cognitive domains and CET performance. These included the Controlled Oral Word Associate (COWA) phonemic verbal uency test for the letters *F*, *A*, and *S* (which measured phonemic verbal uency); semantic uency (animals; Benton & Hamsher, 1989, which measured semantic uency and language functions); the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1978, which measured naming and re ected aspects of semantic memory); and portions of the Wechsler Memory Scale III (WMS III; Wechsler, 1997b), including Logical Memory (LM) I and II and LM

[1] That is, a history of smoking a least a pack of cigarettes per day for 20 years.

[2] Recent considerations have recognized that MCI is a heterogeneous label including a range of clinical manifestations (Lopez et al., 2003; Petersen et al., 2001). The subtypes most relevant to our purposes are patients with mild impairment in learning and memory and relatively normal performance in other domains (an "MCI amnestic only" subtype), patients with memory impairment and mild impairments in at least one other cognitive domain (an "MCI amnestic plus" subtype), and patients with mild impairments in multiple other cognitive domains not involving memory (an "MCI multiple domain" subtype). We explored the possibility that CET performance might vary according to these MCI subgroups. Accordingly, we divided our sample of $N = 73$ MCI participants into the following subgroups, as function of whether each participant fell 1 standard deviation or more below neuropsychological norms in memory function and/or other cognitive domains: MCI amnestic, $n = 14$; MCI amnestic plus, $n = 23$; MCI multiple domain, $n = 29$; MCI no de cit, $n = 7$. These subgroup analyses are reported below.

Table 3
Mean (SD) and Statistics for all Neuropsychological Tests Administered

Tests	NEC	MCI	AD	*F* Ratio[a]	η^2
CET	6.9[b] (2.9)	7.9[c] (3.7)	13.2[b, c] (4.2)	23.87*	.249
BNT	56.1[b, c] (4.8)	47.9[b, d] (8.1)	38.6[c, d] (9.2)	25.20*	.287
Phonemic Fluency	46.3[b, c] (11.7)	33.5[b, d] (11.6)	26.3[c, d] (11.9)	19.63*	.217
Semantic Fluency	18.7[b, c] (4.1)	13.8[b, d] (3.8)	8.6[c, d] (3.9)	41.87*	.369
LM I	14.3[b, c] (3.2)	10.3[b, d] (5.0)	4.8[c, d] (3.1)	30.67*	.305
LM II	12.7[b, c] (3.9)	6.9[b, d] (5.3)	1.4[c, d] (2.1)	43.24*	.382
LM Retained	87.4[b, c] (20.6)	57.5[b] (36.6)	40.8[c] (94.9)	5.05*	.069
Digit Symbol	53.2[b, c] (12.5)	43.4[b, d] (12.2)	31.3[c, d] (14.6)	11.24*	.145
Similarities	22.7[b, c] (6.1)	18.1[b, d] (6.3)	13.3[c, d] (6.6)	9.60*	.124
Block Design	30.9 (11.3)	24.9 (9.0)	18.2 (8.8)	3.03	.050
Digit Span Forward	6.0 (1.2)	5.8 (1.1)	5.4 (1.5)	0.30	.010
Digit Span Backward	4.9 (1.3)	3.8 (1.3)	3.6 (1.3)	1.64	.072
LNS	9.7[b, c] (3.4)	7.53[b] (2.4)	6.17[c] (2.7)	6.84*	.126
Spatial Span Forward	5.3[b, c] (0.6)	4.1[b] (0.8)	4.0[c] (0.9)	6.43*	.130
Spatial Span Backward	4.4[b, c] (0.7)	3.6[b, d] (1.0)	3.0[c, d] (0.9)	5.86*	.121

Note. An asterisk indicates that the univariate *F* test was significant at $p \leq .05$. CET = Cognitive Estimation Test; BNT = Boston Naming Test; LM I = WMS-III Logical Memory immediate recall; LMII = WMS-III Logical Memory delayed recall; LNS = Letter-Number Sequencing.
[a] *F* values corresponding to the analysis of covariance comparing group differences (with the covariates being age and education) are reported. However, to evaluate the actual differences as a function of group, we report the effect size (η^2) of the group main effect and the unadjusted group means. [b, c, d] Group means sharing the same letter superscript differed significantly at the $p < .05$ level.

Retention scores (which measured the percentage of information retained from immediate to delayed recall, which measured immediate and delayed episodic memory) and Spatial Span Forwards and Backwards (which measured general attentional abilities and working memory). We also included several subtests of the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997a), including Block Design (which measured fluid intelligence, perceptual organization, and visual constructional ability), Digit Span Forwards and Backwards (which measured general attentional abilities and immediate and working memory), Letter–Number Sequencing (which measured processing and storage in working memory), Similarities (which measured abstract verbal reasoning), and Digit Symbol (which measured psychomotor control and general speed of processing). The MMSE (Folstein et al., 1975) was also administered to all participants as a measure of global cognitive functioning. Table 3 lists all mean (*SD*) scores for NECs, MCIs, and ADs on these neuropsychological tests.

Statistical Analysis

Performance on neuropsychological tests was assessed with a one-way analysis of covariance (ANCOVA) to examine group differences for all tasks, including the CET, with age and education used as covariates. When significant group differences were present, Tukey's post hoc analyses were conducted.

Results

CET Performance

There was a significant group effect, $F(4, 144) = 18.46, p < .0001, \eta^2 = .249$,[3] indicating that the AD group performed significantly worse than NECs and MCIs but there were no group differences between MCI patients and NECs (see Table 3).[4]

Neuropsychological Test Performance

Table 3 lists the unadjusted mean and *SD* for each group for each neuropsychological task, as well as the corrected model *F* values of the one-way ANCOVAs evaluating group differences. There were significant group differences on a number of neuropsychological tasks. As noted in Table 3, the three groups differed significantly from each other, with AD patients performing more poorly than MCI patients who, in turn, performed more poorly than the NECs on the following tests: the BNT, Phonemic Fluency, Semantic Fluency, LM I and II, Digit Symbol, Similarities, and Spatial Span Backwards.

AD and MCI patients performed significantly worse than NECs on the LM percent retained score, Letter–Number Sequencing, and Spatial Span Forwards, but the performance of the former two groups did not differ significantly from one another.

Correlations and Regression Analyses for CET and Neuropsychological Measures

Pearson's product-moment correlations were computed separately for each group to determine the relationship between neuropsychological test performance and CET performance. The number of participants contributing to each correlation differed from measure to measure because not all neuropsychological tests were

[3] For this analysis and subsequent neuropsychological test score analyses, the *F* values corresponding to the ANCOVA comparing group differences (with the covariates age and education) are reported. However, in order to evaluate the actual differences as a function of group, we report the effect size (η^2) of the group main effect and the unadjusted group means in Table 3.

[4] None of our MCI subgroups differed from the NECs on CET performance with the exception of the "MCI amnestic plus" subgroup, which had a moderately elevated mean CET score of 8.20 (*SD* = 4.2). However, because this score fell well within 1 *SD* of the performance of the NECs, we consider this to be relatively weak evidence for the existence of a meaningful impairment in this subgroup.

Table 4
Correlation Matrix for AD, MCI, and NECs for all Neuropsychological Tasks

AD

Task	CET	MMSE	BNT	Flu-P	Flu-S	LM I	LM II	LM Ret	DSYM	SIMI	BDES	DS F	DS B	LNS	SPA F	SPA B
CET	—															
MMSE	−.211	—														
BNT	−.338*	−.054	—													
Flu-P	−.179	.043	.269	—												
Flu-S	−.267	.055	.545*	.565*	—											
LM I	−.085	.467*	−.199	−.080	.122	—										
LM II	−.208	.141	−.319*	−.292*	−.148	.272	—									
LM Ret	−.218	.049	−.170	−.148	−.042	−.243	.617*	—								
DSYM	−.136	.099	.383*	.275	.305*	.183	−.369*	−.340*	—							
SIMI	−.113	.206	.434*	.741*	.543*	.114*	−.412*	−.323*	.430*	—						
BDES	−.215	.093	−.082	.233	.129	.224	−.119*	.114	.294*	.300*	—					
DS F	−.334	.260	.054	.552*	.345	.162	.055	.026	.281	.513*	.244	—				
DS B	−.085	.239	−.141	.489*	.256	.205	.112	−.039	.063	.513*	.169	.560*	—			
LNS	−.292	.417*	.269	.572*	.356*	.278	−.302	−.287	.296	.653*	.211	.501	.430	—		
SPA F	−.251	.149	−.108	−.083	−.089	.301*	.222	−.020	.253	.132	.409*	.209	.289	.073	—	
SPA B	−.395*	.161	.272	.223	.215	.219	−.034	−.157	.342*	.386*	.303*	.268	.517*	.450*	.311*	—

MCI

	CET	MMSE	BNT	Flu-P	Flu-S	LM I	LM II	LM Ret	DSYM	SIMI	BDES	DS F	DS B	LNS	SPA F	SPA B
CET	—	−.317	−.177	−.159	−.111	−.134	−.128	−.181	−.121	−.128	−.126	−.137	−.035	−.165	.069	.015
MMSE		—	.238*	.068	.240*	.462*	.457	.501*	.317*	.244*	.162	.144	.613*	.176	−.051	.073
BNT			—	.307*	.437*	.145	.150	.138	.219*	.232*	.356*	.101	.375	−.158	−.248*	.037
Flu-P				—	.341*	−.036	−.150	−.168	.333*	.110	.241*	.593*	.353	.040	.217	.095
Flu-S					—	.231*	.313*	.221*	.292*	.315*	.211*	.105	.003	.162	.111	−.038
LM I						—	.798*	.548*	.204*	.446*	.258*	.056	.146	.134	−.118	.070
LM II							—	.874*	.079	.340*	.168	−.080	.388*	.163	−.282*	.045
LM Ret								—	−.048	.235*	.028	−.083	.424*	.137	−.421	−.197
DSYM									—	.241*	.491*	.107	.122	.042	.082	.173
SIMI										—	.524*	.021	−.006	.131	−.032	−.170
BDES											—	.020	.424*	.004	.109	.151
DS F												—	.633*	−.122	−.259	.391*
DS B													—	.083	−.381	.447*
LNS														—	.343	−.004
SPA F															—	.343*
SPA B																—

NEC

	CET	MMSE	BNT	FAS	ANIMAL	LM I	LM II	LM Ret	DSYM	SIMI	BDES	DS F	DS B	LNS	SPA F	SPA B
CET	—															
MMSE	−.146	—														
BNT	−.609*	.355	—													
Flu-P	−.025	.217	−.080	—												
Flu-S	−.326*	.209	.048	.423*	—											
LM I	.063	.100	−.010	−.166	.219	—										
LM II	−.178	.176	.037	−.072	.354*	.820*	—									
LM Ret	−.322*	.110	−.033	.070	.338*	.315*	.766*	—								
DSYM	−.109	.214	−.014	−.094	.150	.550*	.581	.414*	—							
SIMI	−.491*	.130	.242	.203	.447*	.196	.327*	.361*	.244	—						
BDES	−.236	.717*	−.045	.033	.382	.514*	.588*	.461*	.530*	.534*	—					
DS F	−.310	.572*	.187	.158	.306	.549*	.590*	.450*	.390	.258	.382	—				
DS B	−.383	.418	.235	.168	.151	.512*	.503	.079	.301	.281	.499	.677*	—			
LNS	−.451*	.088	.352	.044	.240	.336*	.438	.270	.358*	.559*	.812*	.529	.677*	—		
SPA F	−.355	.395	.116	−.251	.118	.236	.467	.501	.007	.410	.280	.362	.294	.639*	—	
SPA B	−.285	.450	−.066	.168	.414	−.013	.175	.388	−.028	.496	.356	−.241	−.004	.234	.399	—

Note. AD = Alzheimer's disease; MCI = mild cognitive impairment; NECs = normal elderly controls; CET = cognitive estimations test; MMSE = Mini-Mental Status Examination; BNT = Boston Naming Test; Flu-P = Phonemic Fluency; Flu-S = Semantic Fluency; LM I = Logical Memory I; LM II = Logical Memory II; LM Ret = Logical Memory Retention; DSYM = Digit Symbol; SIMI = Similarities; BDES = Block Design; DS F = Digit Span Forwards; DS B = Digit Span Backwards; LNS = Letter-Number Sequencing; SPA F = Spatial Span Forwards; SPA B = Spatial Span Backwards; FAS = verbal uency for letters (f, a, s); ANIMAL = verbal uency for semantic category (animals).
* Correlation is signi cant at .05 (one-tailed).

administered to every participant during their clinical assessment. A negative correlation between CET performance and a given neuropsychological test score was expected, as a high CET score denotes impaired performance. Table 4 lists the values for Pearson's product-moment correlations between CET performance and each neuropsychological test.

When signi cant correlations emerged, a hierarchical regression analysis was performed separately for each subject group to determine the predictive power of these neuropsychological tasks on CET performance. We chose to use hierarchical multiple regression over stepwise regression because, in the former, the order of variable entry is based on theoretical and logical reasoning rather than being solely determined by statistical criteria (Tabachnick & Fidell, 2001). The entry order for each independent variable was based on the assumed proximity between the cognitive domain tapped by the neuropsychological task and the CET. That is, we hypothesized that adequate performance on the CET was dependent on intact executive functioning (most proximal), followed by semantic representations. Therefore, neuropsychological tasks associated with these domains were entered into the analysis last and second to last, respectively, and were preceded by tasks that we hypothesized to be less closely associated with CET performance (e.g., episodic memory). This strategy allowed us to evaluate the contribution of predictors we thought would be closely linked to cognitive estimation, having controlled for the effects of cognitive domains that we believed to be less central. We evaluated the model that included all eligible predictors for signi cance and then evaluated each individual predictor as to whether it contributed signi cantly to the model on the nal step.

Table 5 shows the results of the regression analysis, including the results from the signi cant bivariate correlations between CET performance and the independent variables for each group, the unstandardized regression coef cients (B), the squared semipartial correlations (sr^2), and R and R^2 on the nal step after all the independent variables were entered into the equation. For testing the signi cance of the regression components, F for each variable was based on the change in R^2 (i.e., sr^2), the multiple R^2 after all variables were entered, and the residual degrees of freedom from the ANOVA table for the nal step ($df = 12$ for NECs and $df = 30$ for ADs; see Tabachnick & Fidell, 2001, p. 144).

Normal Elderly Controls

As indicated in Table 4, CET performance in the NEC group correlated signi cantly with BNT, Semantic Fluency, LM Retention scores, Similarities, and Letter–Number Sequencing. The variables were entered into the regression analysis in the following order: LM Retention, BNT, Semantic Fluency, and Similarities. A statistically signi cant model that included all of these variables, $R = .76, F(4, 12) = 3.98, p < .028$, was obtained, and it indicated that the BNT signi cantly accounted for 38% of the variance associated with CET performance ($p < .05$). LM Retention scores, Semantic Fluency, and Similarities were no longer signi cant predictors of CET performance when all predictors were tested on the nal step (see Table 5).

With regard to the second cohort of NE participants, we found that Semantic Fluency, Similarities, and WCST perseverative errors correlated signi cantly with CET performance (see Table 5). Similar to our approach for the clinical groups analyses, we examined these relationships in a hierarchical regression analysis. The nal model including these variables was signi cant, $R = .66$, $F(3, 35) = 8.90, p < .001$, and indicated that Semantic Fluency, Similarities, and WCST perseverative errors each explained a signi cant and unique amount of variance of CET performance (see Table 5).

Table 5
Hierarchical Regression on CET Performance in Normal Elderly Control (NEC) and Alzheimer's Disease (AD) Participants and the Second Cohort of Normal Elderly (NE) Participants

Group	Step	Variable	R with CET	B	β	sr^2
		Intercept = 30.88, $R^2 = .57$, adjusted $R^2 = .43$, $R = .76$				
NEC	1	LM Retention	−.27	.004	.036	.07
	2	BNT	−.61	−.331	−.523	.38*
	3	Animal uency	−.34	−.115	−.156	.06
	4	Similarities	−.57	−.174	−.367	.06
		Intercept = 21.63, $R^2 = .21$, adjusted $R^2 = .16$, $R = .46$				
AD	1	Spatial Span backwards	−.40	−1.43	−.33	.16*
	2	BNT	−.34	−.107	−.25	.06
		Intercept = 16.96, $R^2 = .43$, adjusted $R^2 = .38$, $R = .66$				
NE[a]	1	Animal uency	−.49	−0.27	−.29	.24*
	2	Similarities	−.52	−0.44	−.30	.12*
	3	WCST % errors	.46	.10	.29	.07*

Note. CET = cognitive estimations test; LM = logical memory; BNT = Boston Naming Test; WCST = Wisconsin Card Sorting Test.
[a] NE here refers to the second cohort of normal elderly participants ($n = 39$) reported.
* $p < .05$

Mild Cognitive Impairment

Despite the large sample size of patients, there were no significant correlations between CET performance and neuropsychological measures for the MCI Group.[5]

Alzheimer's Disease

Among the AD patients, CET performance correlated significantly with the BNT and Spatial Span Backwards test. The correlation between Semantic Fluency test scores and CET performance just missed conventional significance ($r = -0.27, p = .055$). A hierarchical regression model was performed with Spatial Span Backwards and BNT entered first and second, respectively. The final model which included both predictors of CET performance was statistically significant, $R = .46, F(2, 30) = 4.03, p < .028$. Performance on the Spatial Span Backwards task significantly accounted for 16% of the variance ($p < .05$), whereas the BNT was no longer a significant predictor on the final step (see Table 5).

Discussion

One purpose of this study was to examine whether we could distinguish between patients with dementia and NECs using the CET. AD patients performed significantly more poorly than MCIs, but MCIs were not impaired as evidenced by the nonsignificant difference between MCIs and NECs on this test. A second goal of this study was to examine which cognitive components were involved in CET performance. We hypothesized that there would be a relationship between CET performance and executive functioning tasks. However, previous studies have suggested that the CET also involves semantic representation (Goldstein et al., 1996). We found evidence to support both of these notions. We shall now discuss these main results in turn.

The significant difference in performance between NEC and AD patients on the CET agree with the results of Goldstein et al. (1996). These results are also consistent with recent studies that suggest that AD patients manifest significant executive functioning impairments, even at an early stage of the disease (Baddeley, Baddeley, Bucks, & Wilcock, 2001; Balota & Faust, 2002; Binetti et al., 1996; Brand et al., 2003; Collette et al., 1999; Duke & Kaszniak, 2000; Goldstein et al., 1996; Perry & Hodges, 1999, 2000b; Perry et al., 2000). These impairments range from dysfunction associated with working memory performance to impairment in judgment and reasoning.

With respect to the second goal of the study, we found significant negative correlations between CET performance and tasks of working memory and semantic memory for both NECs and AD patients. Specifically, CET performance correlated significantly with BNT, Semantic Fluency, and Letter–Number Sequencing in the NECs and with BNT and Spatial Span Backwards in the AD patients. It is interesting that for the NEC group, when the BNT and Letter–Number Sequencing tasks were entered into the hierarchical regression analysis, the BNT emerged as the only significant predictor of CET performance. At first glance, this would suggest that adequate performance on the CET is predominantly dependent on semantic representation tasks as indexed by the BNT. However, in the AD group, when the Spatial Span Backwards task and BNT were entered into the hierarchical regression analysis, the BNT did not emerge as a significant predictor of CET performance after controlling for performance on the Spatial Span Backwards task.

How might we account for the different findings between these two groups as seen in the regression analyses? We offer the following preliminary model for the reader to consider. First, it is logical to conclude that NECs had intact working memory, as displayed by adequate performance on tasks such as Letter–Number Sequencing, Digit Span Forward and Backwards, and Spatial Span Forward and Backwards. Thus, a combination of intact working memory and semantic abilities should enable the NECs to perform well on the CET, because they are able to maintain semantic information in working memory in order to estimate a plausible solution to each question. For example, when required to estimate the height of a giraffe, it likely is necessary to maintain several pieces of semantic information in working memory (such as the size of the giraffe in relation to other tall objects, estimating the height of those other objects, generating a proportional value, etc.). Therefore, to formulate a plausible answer using judgment and reasoning, it is necessary to maintain relevant semantic information in working memory. However, the AD patients in this study were significantly impaired on working memory tasks (as displayed by their poor performance levels on the Spatial Span Forward and Backwards, and Letter–Number Sequencing tasks) and on tests of semantic ability (as evidenced by their impaired performance on tasks of fluency, naming, and similarities). As such, not only would the AD patients have difficulty accessing semantic information required for a CET question, but they would also have difficulty holding relevant information in working memory to formulate a solution. That is, without adequate working memory, AD patients would likely be unable to maintain any semantic information to adequately estimate plausible answers to the solutions on the CET. If this rudimentary model is correct, it cautions against interpreting the CET (and many other measures) as a pure executive task and suggests that the CET may be subject to the concerns regarding task impurity expressed by Miyake, Friedman, Emerson, Witzki, & Howerter (2000). A recent review by Royall et al. (2002) distinguished between two conceptualizations of executive processes, namely executive functions as they pertain to higher order abilities such as reasoning and abstraction (a somewhat older conceptualization) versus executive functions that control the execution of other nonexecutive cognitive processes. In our opinion, the CET encompasses aspects of both, where deficits in working memory undermine the control of abstraction and reasoning along with other nonexecutive abilities (such as semantic memory).

The results from our second group of normal elderly participants tested (the NEs) indicated that perseverative errors on the WCST predict performance on the CET, strengthening the argument that it is indeed sensitive to some aspects of executive functioning. This is especially notable given that perseverative errors are the metric of the WCST considered most sensitive to executive impairment (Lezak, 1995; Milner, 1963; Mountain & Snow, 1993). Unfortunately, our clinical test battery was weak in tasks aimed at measuring executive

[5] Correlations conducted for the MCI subgroups did not yield any significant two-tailed correlations between CET scores and performance on other neuropsychological tests.

functioning. Whereas tasks such as Spatial Span Forwards and Backwards, Digit Span Forwards and Backwards, Letter–Number Sequencing, and Verbal Fluency were included in the clinical test battery, these tests are best conceptualized as working memory measures (with the exception of verbal uency). Other measures such as the WCST, the Tower of Hanoi Task, the Stroop Task, and the Trail Making Test, Part B, are more typically considered measures of executive functioning but were not included in our clinical neuropsychological dementia test battery because these tasks can be dif cult and fatiguing to perform for impaired patients. Consequently, we must be cautious in our interpretations.

As a group, the MCI participants did not differ signi cantly from the NEC participants on CET performance, indicating that, with few exceptions, they performed within normal limits on this task. However, in contrast to the results for the NECs and despite our large sample size, we failed to nd any signi cant correlations between CET performance and neuropsychological test scores within the MCI group. There are several possibilities to account for this unexpected null result. First, it is possible that our large group of MCI participants constituted a heterogeneous cohort. As such, some of these patients will either progress to develop AD, thereby manifesting cognitive impairments that are within similar ranges of AD patients, and some will remain as nonprogressors, with cognitive impairment that neither improves nor worsens. Second, the range and nature of cognitive pro les and impairments within this group may have varied so widely as to preclude correlations between the CET and other tasks. We explored this possibility by dividing our patients into MCI subgroups and still no signi cant effects were observed. MCI patients are usually distinguished from ADs and NECs on the basis of episodic memory task performance (Chertkow, 2002; Collie & Maruff, 2000; Flicker et al., 1991; Petersen, 2000; Petersen et al., 2001, 1999), which we observed in this study as well. However, our MCI patients were also impaired on semantic memory tasks (e.g., BNT, Semantic Fluency, and Similarities) at least according to the group means. Other studies have also reported mild impairment in MCI patients on semantic tasks such as the BNT (e.g., Petersen et al., 1999) and Semantic Fluency (e.g., Phillips, Chertkow, LeBlanc, Pim, & Murtha, 2004). As well, executive functioning impairments have been noted in MCI patients (e.g., Haninen et al., 1997; Tierney et al., 1996). Perhaps, because the MCI sample showed only mild de cits in episodic, semantic, and working memory (as a group), these factors were not powerful enough to predict their CET performance.

To investigate further the hypothesis that semantic memory contributes signi cantly to CET performance, we also tested two patients with semantic dementia. These two patients, aged 72 and 75 (MMSE scores of 24 and 23, respectively), both showed marked anomia and loss of semantic knowledge on various tasks, the latter being the predominant symptom of their dementia. They both displayed remarkably impaired performance on the CET (scores = 19 and 19) compared with the entire cohort of patients. In addition, their neuropsychological test results indicated that they were more impaired on tasks of semantic association compared with the AD patients. This evidence, in addition to the results suggested by the hierarchical regression analyses performed on the NEC and AD groups, indicate that semantic memory contributes signi cantly to CET performance.

In the future, it would be interesting to compare patients with different forms of dementia (such as FTD and Vascular Dementia patients) to evaluate their performance on the CET compared with normal controls. For example, one would assume that if the CET were a sensitive measure of executive functioning, then FTD patients with frontal signs would perform poorly on the CET. However, in the study conducted by Mendez et al. (1998), AD patients performed more poorly than FTD patients. In that study, the AD patients had lower MMSE values than the FTD patients, which suggests that their more severe dementia could have accounted for impaired CET performance as opposed to speci c semantic or executive functioning impairments.

With regard to lesion patients, the ndings are inconclusive. Shallice and Evans (1978) originally tested CET performance in focal lesion patients. They suggested that patients with frontal lobe lesions performed signi cantly worse than patients with parietal lobe lesions on the CET. However, Taylor and O'Carroll (1995) showed discrepant results. Therefore, to re ne the relationship between CET and neuropsychological task performance, further research should be conducted using these speci c patient groups and with more pure measures of speci c cognitive constructs. These studies would resolve the discrepant ndings and further add to the theoretical and clinical research on executive functioning impairments in patients with FTD, as well as patients with localized lesions.

In conclusion, our data indicate that cognitive estimation is impaired in AD but is intact in patients with MCI. On the basis of the pattern of results from our two groups of healthy elderly participants and patients with AD, we conclude that although the CET is sensitive to aspects of executive function (as per the relationship with WCST perseverative errors), it is not a pure measure. The performance of our NEC and AD participants highlight the importance of semantic memory and working memory contributions to cognitive estimation performance.

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