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The cognitive mechanisms underlying perspective taking between conversational partners: Evidence from speakers with Alzheimer's disease

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Abstract

Successful communication requires speakers to consider their listeners' perspectives. Little is known about how this ability changes in Alzheimer's Disease (AD) although such knowledge could reveal the cognitive mechanisms fundamental to perspective-taking ability, and reveal which cognitive deficits are fundamental to communication disorders in AD. Patients with mild to moderate AD and age and education matched controls were tested in a communicative perspective-taking task, and on measures of executive control, general cognitive functioning, and lexical retrieval. Patients' ability to perform the perspective-taking task was significantly correlated with performance on measures of general cognitive functioning, visual scanning and construction, response conflict and attention. Measures of lexical retrieval tended not to be correlated with performance on the communication task with one exception: semantic but not letter fluency predicted a derived score of perspective-taking ability. These findings broaden our understanding of the cognitive mechanisms underlying perspective taking, and suggest that impairments in perspective taking in AD occur during utterance planning, and at a relatively early processing stage which involves rapid visual scanning and problem solving, rather than during retrieval of lexical items needed to speak. More broadly, these data reveal executive function and semantic deficits, but not problems with lexical retrieval, as more fundamental to the basis of cognitive changes associated with AD.

1.0 Introduction

Communication allows people to reveal their needs, thoughts, feelings and desires, placing it at the heart of most human relationships. Communicative impairments associated with

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Alzheimer's Disease (AD) can lead to interpersonal conflict, social isolation and depression (Orange & Colton-Hudson, 1998; Small, Geldart, Gutman, & Clarke Scott, 1998; Small, Montoro, & Kemper, 1996; Williamson & Shultz, 1993). The current research employs psycholinguistic approaches to study the cognitive mechanisms underlying communication deficits in AD, a greater understanding of which will serve to inform models of cognitive impairments in AD.

Speakers often have a different perspective than their listeners. Thus, to communicate effectively, speakers must take into account the differences between their own knowledge and perspectives, and that of the people they are speaking to. This process is referred to as *perspective taking*. The need to take others' perspective into account is especially apparent when making references to specific objects. For example, if a customer standing in front of a display case full of pastries simply says, "I'll take that one," with no other accompanying gesture or words, she will not get the desired object because she failed to take perspective differences into account. Past research reveals that persons with AD often struggle to refer to things effectively (Blanken, Dittmann, Haas, & Wallesch, 1987; Bucks, Singh, Cuerden, & Wilcock, 2000; Carlomagno, Santoro, Menditti, Pandolfi, & Marini, 2005; Feyereisen, Berrewaerts, & Hupet, 2007). Miscommunication of references has practical negative consequences. For example, caregivers and patients could leave each other confused and misinformed because of a failure to appreciate perspective differences. The current study examines how AD changes speakers' ability to take their listeners' perspective in a verbal communication task and links this performance to processing models of both perspective taking itself and, more broadly, to cognitive decline in AD. In addition, by examining the relationships between perspective taking and neuropsychological measures in AD, we can gain insight into which neural correlates might underlie perspective taking ability in all speakers.

According to Nilsen and Fecica's (2011) theoretical model, taking perspective into account when producing language requires the ability to mentalize. This refers to the ability to understand that a listener has a different mental state or mental model than the speaker. We propose that if perspective-taking errors in AD are the result of impairments in the ability to mentalize, then measures of general cognitive abilities should correlate with perspective-taking performance. Furthermore, past research on referencing performance in patients with AD suggested that their perspective-taking impairments could be due to difficulty at the conceptual level of production (Carlomagno et al., 2005). Conceptual-level impairments themselves should be related to performance on measures of general cognitive functioning insofar as conceptually determining one's message is a process related to understanding the world around oneself. If so, perspective-taking impairments should be most closely associated with measures of general cognitive functioning, conceptual knowledge, and semantic processing, as these appear central to the meaningful interpretation of situations.

Another possibility is that communicative perspective taking could depend upon lexical retrieval abilities specifically as the ability to retrieve lexical representations provides speakers with the means to encode the words that best convey an intended meaning. On this view, even if perspective taking can occur at a non-linguistic, conceptual level (and even if it normally does occur at this level), it will inevitably be influenced by lexical accessibility

when perspective is communicated with words and sentences (as in the task described below). For example, if speakers have difficulty retrieving words that convey their message, they will have fewer cognitive resources for making sure that the words they are planning to produce will accurately convey an intended message. If so, perspective-taking errors might be correlated with measures of retrieval of the names needed to express their thoughts.

In this respect, patients' performance on a perspective-taking task could contribute to a broader debate in the literature on cognitive decline in AD. According to the Storage Loss account, AD primarily entails a progressive deterioration of semantic knowledge (e.g., Butters, Granholm, Salmon, Grant, & Wolfe, 1987) resulting from impairment to neocortical association areas. Supporting this view, patients with mild AD exhibit a relatively spared ability to rapidly generate words beginning with the letters F, A, and S, but have more difficulty with semantic categories (Monsch, Bondi, Butters, Paulsen, Salmon et al., 1994). Additionally, longitudinal studies also reveal greater decline of semantic than letter fluency with disease progression, and greater consistency of response failures than seen in controls, implying permanent loss of semantic category members (Salmon, Butters, & Chan, 1999).

An alternative, the Retrieval Deficit account, proposes that AD primarily impairs retrieval from a relatively intact semantic store (Nebes, Martin, & Horn, 1984). On this view, semantic memory remains relatively unchanged in early AD, and deficits reflect impaired access to lexical representations. Consistent with this proposal, patients with AD exhibit intact semantic priming effects (Nebes & Brady, 1990), and deficits are more salient when retrieval is difficult (e.g., in producing low-frequency picture names: Hodges, Patterson, Oxbury, & Funnell, 1992; Kirshner, Webb, & Kelly, 1984; Ober & Shenaut, 1988; Thompson-Schill, D'Esposito, & Kan, 1999). Support for the Storage Loss account would come from finding that perspective taking is most closely related to measures of general cognitive ability and semantic integrity (e.g., the semantic fluency task). In contrast, the Retrieval Loss account would be supported if measures of lexical retrieval (e.g., the Boston Naming Test, and phonemic fluency) were most closely related to perspective-taking errors.

A third possibility is that perspective-taking errors stem from deficits in executive control, including working memory (Wardlow, 2013; and as suggested by Lin, Keysar, & Epley, 2010), attention (Wardlow Lane & Ferreira, 2008) and inhibitory control (Wardlow, 2013; and as suggested by Brown-Schmidt, 2009), all of which are commonly impaired in the early stages of AD (Amieva, Philips, Della Sala, & Henry, 2004; Perry & Hodges, 1999). Executive control impairments could weaken patients' abilities to attend to perspective differences, to inhibit their own perspective, or to adjust their utterances while keeping in mind their listener's perspective. If so, we would expect that perspective-taking impairments would be most closely associated with measures of executive functioning. A final possibility is that some combination of these factors best accounts for perspective-taking performance.

To test these possibilities, in the current study, patients with mild to moderate AD and an age and education matched control group participated as speakers in a referential communication task in which speakers and listeners had different perspectives on arrays of items during face-to-face interaction. Both groups also completed measures of general cognitive functioning, lexical retrieval, and executive control. To successfully refer,

speakers must take into account the differences between their perspectives and their listeners' perspectives. To do so, information must be delineated as mutually known (i.e., in *common ground*), or privileged (i.e., known only to the speaker: Clark & Marshall, 1981; Stalnaker, 1978). There are two general categories of perspective taking errors that speakers make. One of these, a *common ground error*, is the consequence of not taking into account the fact that multiple similar objects in common ground create multiple potential targets for the listener. For example, imagine an array of shoes, some of which are visible to both speaker and listener (in common ground). A common ground error occurs when a speaker refers to one specific mutually visible shoe as "the shoe," failing to account for the fact that there are multiple shoes in common ground. Instead, the speaker should have specified which shoe was being referred to ("the big shoe", for example). This type of perspective taking is relatively easy as evidenced by the fact that unimpaired adults do not typically make this kind of perspective-taking error under normal task conditions (Wardlow Lane, Groisman, & Ferreira, 2006; Wardlow, 2013) although children up to about 6 years of age do (Nadig & Sedivy, 2002; Nilsen & Graham, 2009).

The other type of perspective-taking error is a *privileged ground error*. This type of error is the consequence of failing to account for the fact that privileged objects are *not* potential targets for the listener. For example, imagine another array of shoes. However, in this array there is only one mutually visible shoe and one shoe that is privileged to the speaker. A privileged ground error occurs when the speaker refers to the mutually visible shoe as "the big shoe," rather than "the shoe" (since the listener can only see one shoe), precisely because there is a smaller shoe that is privileged. This type of perspective taking is more difficult than common ground processing as evidenced by the fact that privileged ground errors are seen relatively commonly in both cognitively healthy young adults (and children; Wardlow Lane, Groisman, & Ferreira, 2006; Wardlow Lane & Ferreira, 2008; Nadig & Sedivy, 2002). One possibility is that speakers with AD may have insufficient cognitive resources to adjust perspective in this manner altogether (in which case the simpler *common ground* trials may be of greater interest in the current study).

2.1 Materials and Methods

2.2 Participants

Nineteen patients, and 18 cognitively healthy controls matched on average for age and education level to the patients, were recruited to participate from the Shiley-Marcos UCSD Alzheimer's Disease Research Center (ADRC). Diagnosis was established by administration and analysis of a neuropsychological test battery and neurological examination at the ADRC. See Table 1 for participant characteristics and between-group comparisons. Diagnoses were made using criteria developed by the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) and the Alzheimer's Disease and Related Disorders Association (ADRDA; McKhann, Drachman, Folstein, Katzman, Price, et al., 1984).

2.2. Assessment of Perspective-taking

Participants were tested as speakers in a referential communication task modeled after Wardlow Lane and Ferreira (2008). Participants were paired with a research assistant, who played the role of the listener while another research assistant administered the task (see Figure 1). Participants viewed 144 simple line drawings of common objects in total, four of which were displayed per array on a sheet of 8 1/2" by 11" paper, creating 36 trials. Each object appeared on one trial per subject and appeared either as the only object of its type in the display or with one pair mate that varied only in size. Displays for all trial types contained either one pair or two pairs of like objects so that trial type was not decipherable from the display alone. Each target object appeared in all 3 trial type conditions across subjects, creating 3 subject groups for each participant group (AD vs. Control). Objects varied in actual size within and between trials such that the size of a given object relative to the size of the other objects on the same trial could be large on some trials and small on others. Locations of targets were randomly distributed and as such targets and contrasts were only sometimes adjacent.

At the beginning of the testing session, a research assistant read a set of instructions to the speaker and then administered a set of three practice trials during which the participant acted as the listener and the other research assistant acted as the speaker. This was done to provide the participant with the experience of having an object blocked from view. An additional three practice trials were completed, this time with the participant acting as the speaker and the research assistant acting as the listener. Three additional practice trials were administered halfway through the task. Participants acted as listeners on these latter trials to reinforce how the listener's perspective differed from the speaker's perspective.

At the beginning of each trial, the listener (research assistant) closed her eyes so that the four objects could be revealed to the speaker (experimental participant). The testing research assistant then placed an occluder in front of one of the objects so that the speaker could see it, but when the listener opened her eyes, she would not be able to see that object. The result was that three of the objects were mutually visible (in common ground) and an additional one was visible only to the speaker (in the speaker's privileged ground). That is, although the listener could see a subset of the objects (in Figure 1, a large triangle, a small triangle and a circle), the speaker could see an additional object (in Figure 1, a large circle). When placing the occluder, the research assistant said, "I'm going to block this object so that the listener will not be able to see it". This was meant to reinforce that object's privileged status to the speaker.

The research assistant then pointed to the target object and said, "Please ask her to point to this one." If the speaker was having trouble with that instruction and pointing to the object himself or herself, the instruction was changed to, "please name this one for her". On all critical trials, targets were mutually visible (i.e., visible to both speaker and listener), and medium-sized, so use of a size-contrasting modifier should indicate something more about the relationship of the target to other objects in the set rather than about the target itself. On baseline trials, targets were unique to the set to assess how often references included modifiers irrespective of the contrast to an object of the same type in the set.

Common Ground Errors—After the object was named, the listener opened her eyes, scanned the objects on the sheet and then pointed to the object that best matched the speakers' reference. On common ground trials (see Figure 2), mutually visible foils were the same shape as the target. Here, speakers need to produce a size-contrasting modifier (e.g., *the small triangle*) so the listener could pick out the target from the set. Failure to produce a modifier on common ground trials is considered a *common ground error*. When a common ground error was made, listeners (the research assistants) were instructed to hesitate by scanning the set of objects for two seconds, and then alternating between pointing to the actual target on half of trials where a common ground error was produced, and pointing to the foil on the other half. This was meant to approximate performance of a naïve participant. Listeners did not provide verbal feedback about errors.

Privileged Ground Errors—On privileged ground trials, foils were the same shape as the target, but foils were visible to speakers only (see Figure 2). Here, use of a size-contrasting modifier to differentiate the target from a foil that is not visible to the listener is considered a *privileged ground error*. The best perspective-taking performance on privileged ground trials is to not use a modifier to describe a target (e.g., to simply say *the triangle* instead of *the small triangle* even though the speaker sees two size-contrasting triangles). When speakers produced privileged ground errors, listeners were instructed to hesitate by scanning the set of objects for an extra two seconds as if looking for the contrasting object, and then point to the target. Again, listener behavior was designed to approximate performance of a naïve participant.

On a third type of trial, baseline trials, targets were the only shape of that type in the set (e.g., the only triangle in the array). Baseline trials provided an assessment of how often size-contrasting modifiers were used to describe targets irrespective of the contrast to the foil rather than as a measure of perspective taking.

After a reference was made and the listener pointed to an object, the speaker was instructed to tell the listener whether the choice was correct. If speakers had difficulty with this, the research assistant told the speaker and listener whether the listener's choice was correct.

Task Order—As part of their annual Neuropsychological Assessment at the ADRC, participants completed a number of neuropsychological tests described in sections 2.3–2.5. The perspective-taking task, Flanker task and Hayling task were administered on a different day than the Neuropsychological Assessment either at the ADRC or at patients' homes. At these testing sessions, participants completed the perspective-taking task first, followed by the Flanker task and then the Hayling task. The mean time between the two testing sessions did not vary by participant group; $M = 4.6$ months, $SD = 4.6$ for the Control group and $M = 4.5$ months, $SD = 3.7$ for the AD group.

2.3. General Cognitive Functioning

Dementia Rating Scale (DRS; Mattis, 1988)—The DRS is a standardized test of mental status with 144 possible points, and subscales for Attention (37 points), Initiation and Perseveration (39 points), Construction (6 points), Conceptualization (37 points), and Memory (25 points).

Mini Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975)—The MMSE is a brief, standardized 30-point scale that assesses orientation to time and place, attention and concentration, recall, language, and visual construction.

Block Design (WISC-R, Wechsler, 1974)—This test assesses visuospatial functioning and reasoning by having participants create specific geometrical patterns using colored blocks.

2.4. Lexical and Semantic Retrieval

Verbal Fluency Test (VFT; Thurstone & Thurstone, 1941)—In the VFT, participants are asked to produce as many exemplars from a given category as possible within a minute. Participants completed three semantic categories (*Animals*, *Fruits*, and *Vegetables*), and three letter categories (in which they were asked to produce words that begin with F, A, and S). VFT scores are based on number of unique words produced, excluding repetitions and morphological variants (e.g., horse, horses).

Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1983)—Participants were asked to name 30 black and white line drawings of objects (odd items from the Boston Naming Test). The pictures are graded in difficulty with the easiest drawings presented first. If a participant encounters difficulty in naming an object, a semantic or phonemic cue is provided. Correct responses produced spontaneously and after semantic (but not phonemic) cues are summed to provide a total score (with maximum of 30).

2.5. Executive Functioning

Forward and Backward Digit Span (Wechsler, 1997)—On the Forward Digit Span task, participants hear and recall increasingly longer strings of numbers in serial order. The Backward Digit Span task requires participants to repeat back number strings in reversed order from which they were presented. Participants receive one point for every sequence they are able to repeat correctly.

Trail Making Test A and B (TMT A and TMT B; from the Halstead Reitan Neuropsychological Test Battery; see Reitan, 1958; cf. Mickes, Wixted, Fennema-Notestine, Galasko, Bondi, et al., 2007)—In Part A (TMT-A), participants draw a line to connect the numbers 1–25 in consecutive order as quickly as possible within a 150 second time limit. In Part B (TMT-B), participants draw a line to connect 25 numbers and letters in alternating, consecutive order as quickly as possible within a 300 second time limit. The time to complete each task, and the errors made, are scored.

Flanker Task (based on the Attentional Network Task; Fan, McCandlis, Sommer, Raz, & Posner, 2002)—This task assesses selective attention and ability to resolve response conflict. Participants are asked to indicate the direction of a center arrow by pressing a key with their left hand if the arrow is pointing left, or with their right hand if the arrow is pointing right. The center arrow is surrounded by horizontal lines or arrows (two on each side of the center arrow). In the current study, the center arrow was red and was

surrounded by black flanking lines or arrows. Pilot testing revealed it was necessary to make the center arrow red to make the task sufficiently easy for patients to complete. Targets were 32 congruent displays (five arrows pointing in the same direction), 32 neutral displays (a single arrow flanked by lines without arrow-heads), and 32 incongruent displays (a center arrow flanked by two arrows on each side pointing in the opposite direction of the center arrow). These displays were evenly divided between left- and right-pointing center arrows and randomly presented. Participants were requested to indicate by a button press in which direction the central arrow pointed. For this purpose, they were asked to position the index fingers of both hands on the “z” and “?” keys of the computer keyboard, and to respond with their left or right index fingers to left- or right-pointing central arrows, respectively.

Trials included a 500 ms central fixation point, followed by the target stimulus until a response was recorded. The inter-trial interval was 500 ms. Practice blocks began with six neutral trials, followed by six congruent trials, then six incongruent trials, and then six trials with equal numbers of the different conditions in random order. Stimuli were presented on an Apple MacBook laptop with a 15-inch display using PsyScope 1.2.5 (Cohen, MacWhinney, Flatt, & Provost, 1993).

Hayling Task (based on Burgess & Shallice, 1997)—This task assesses verbal inhibitory control. Participants were presented with spoken high cloze sentences of two types. On automatic trials, participants were instructed to say as quickly as possible the first word that came to mind that ended each sentence in a sensible way. For example, “Cats see well at (night).” On inhibitory trials, participants were instructed to say as quickly as possible the first word that came to mind that was completely unrelated to the sentence and made no sense at all. For example, “Cats see well at (potato).” Each sentence was presented in both conditions across halves (i.e., a particular sentence that was presented in the first half in the automatic condition was presented in the second half in the inhibitory condition, and vice versa). Materials were created and normed with 11 native English speakers. Only sentences that were completed with the expected target by 70% of respondents were included. Overall, respondents produced the intended target at a mean rate of 0.97, $SD = .07$.

Two dependent measures were used: response time and error rate. A stopwatch was started at the completion of the last word of the spoken sentence and stopped when the participant began producing a response. An average response time for each condition was then computed for each participant including only non-error trials. A scoring system was used based upon Shallice and Burgess (1996) and Belleville, Rouleau, & Van der Linden (2006). In the automatic condition, a score of 0 was given on trials where the participant produced the expected target response. A score of 1 was given when a semantically related or opposite response was provided (for example, “dark” instead of “light”). A score of 3 was given when participants produced a response that was completely unrelated to the target. In the inhibitory condition, a score of 0 was given when participants produced a response that was unrelated to the target. A score of 1 was given when the response was semantically related or the opposite of the target response. A score of 3 was given when participants produced the target expected in the automatic condition. An average error rate for each condition was computed for each participant.

3. Results

3.1 Perspective-taking task performance

Figure 3 reports the mean proportions of context-relevant modifiers (e.g., “big” or “small”) used in the common and privileged ground conditions. On average, modifiers were used more often in the common ground condition (where use of a modifier was absolutely necessary for the listener to be able to correctly determine the identity of the target object), as compared to the privileged ground condition. The AD group used fewer modifiers on common ground trials (71%) than the Control group (97%) but modifier use was similar for the two groups on privileged ground trials (51% of trials in the AD group and 46% of trials in the Control group) and on baseline trials (<1% for both groups). Common ground and privileged ground measures were combined into a single *perspective-taking difference score*, which was calculated by subtracting the mean modifiers used on privileged ground trials from the mean modifiers used on common ground trials for each participant. The larger the difference score, the better participants accommodated perspective differences (i.e., using modifiers where they should be used, but not using them where they would confuse the listener). The AD group had a significantly smaller difference score (19%) than the control group (50%).

Statistical analyses supported these observations. We analyzed the data by means of logistic mixed-effects regression (LMER) modeling. We modeled the log odds (logit) of modifier use in each perspective-taking condition (common ground or privileged ground) as a linear function of diagnosis (AD, control), with the interaction between perspective-taking condition and diagnosis included as a predictor. This statistical technique has recently been recommended by Dixon (2008) for modeling categorical data (e.g., accuracy), and addresses a number of shortcomings with traditional ANOVA analyses in repeated measures designs (Baayen, 2008; Baayen, Davidson, & Bates, 2008; Jaeger, 2008; Pinheiro & Bates, 2000; Richter, 2006). For these logistic regressions we used the lme4 package (Bates, Maechler & Bolker, 2012) in the statistical software R (version 2.15.2; The R Foundation for Statistical Computing, 2012). We specified both subjects and items as random effects (Formula: $\text{Transcription} \sim \text{SpeakerGroup} * \text{TrialType} + (\text{TrialType} | \text{Subject}) + (\text{SpeakerGroup} * \text{TrialType} | \text{Item})$), and used orthogonal contrast coding. The addition of random slopes for all repeated measures variables allows for the observed within-subject effects to vary across subjects and within-item effects to vary across items. One subject from the AD group was removed from this analysis due to missing trial-level data.

Results revealed that participants in the control group produced marginally more modifiers than participants in the AD group ($\text{coefficient} = -1.70$, $SE = 0.93$, $\text{Wald } Z = -1.83$, $p < .07$). Participants produced more modifiers on common ground than on privileged ground trials ($\text{coefficient} = -3.62$, $SE = 0.78$, $\text{Wald } Z = -4.67$, $p < .001$), and the interaction between speaker group and trial type was significant ($\text{coefficient} = 3.68$, $SE = 1.54$, $\text{Wald } Z = 2.39$, $p < .02$), reflecting that the AD group used fewer modifiers than Controls in the common ground condition but a similar number of modifiers in the privileged ground condition, relative to the Control group.¹

3.2. Flanker task performance

Data were collected from 16 patients with AD and 16 controls because three patients with AD and two controls were unavailable for testing on the flanker task. One additional patient only completed 34 out of 48 trials of the flanker task due to fatigue. Reaction times exceeding two standard deviations from each participant's mean were discarded from the analyses leading to the removal of 3.6% of correct responses for the AD group, and 5.5% for the control group.

An examination of participants' performance on this task suggests that patients responded more slowly than controls in all conditions, and that responses were slower on incongruent trials than on both congruent and neutral trials (a Flanker effect; see Table 1). Participants in both groups committed very few errors, and these did not seem to vary systematically between conditions. Error rates revealed no significant differences between patients and controls except for in the incongruent condition (see Table 1), and we do not discuss them further. Statistical analyses supported these observations. Analyses were performed by means of LMER models including random intercepts and slopes for subjects. First, we explored whether reaction times in the incongruent condition differed from reaction times in both the incongruent and neutral conditions. For this reason, we fitted a LMER model to the data, with group (AD, control) and trial type (incongruent, congruent + neutral) as fixed predictors. The fixed predictors were converted to numerical values with a range of 0.5 and a mean of 0, whereby the incongruent condition was assigned a value of 0.5, and both the congruent and neutral condition, values of -0.25 .

Results revealed that group was a significant predictor [*coefficient* = 162.61, *SE* = 52.11, *t* = 3.12, *p* = .002], such that the AD group responded more slowly (772 ms) than the Control group (607 ms). Trial type was also a significant predictor [*coefficient* = 36.29, *SE* = 11.55, *t* = 3.14, *p* = .002], such that reaction times in the incongruent condition were slower (710) than reaction times in the congruent and neutral condition together (679) – a flanker effect. The interaction term between group and trial type was marginal [*coefficient* = 39.39, *SE* = 23.09, *t* = 1.71, *p* = .09]. Shedding light on this interaction, simple effects indicated that, whereas there was a significant effect of trial type for the AD group [*coefficient* = 41.99, *SE* = 12.01, *t* = 3.50, *p* < .001], there was no such effect for the Control group [*coefficient* = 12.45, *SE* = 12.48, *t* = 1.00, *p* = .32], likely due to ceiling performance for this group because of the simplified nature of the flanker task we employed (see Method section). A further LMER model explored whether reaction times in the congruent and neutral conditions differed from each other. Group was again a significant predictor [*coefficient* = 162.31, *SE* = 52.16, *t* = 3.11, *p* = .002], but neither trial type [*coefficient* = -7.81 , *SE* = 11.22, *t* = -0.70 , *p* = .49] nor the interaction between group and trial type [*coefficient* = -1.31 , *SE* = 22.44, *t* = -0.06 , *p* = .95] were significant predictors, suggesting that there was

¹For those readers more familiar with ANOVA analyses, we also conducted a 3×2 ANOVA on the proportions of modifiers used by subject with the factors trial type (common ground, privileged ground, baseline) and group (AD, Control). This ANOVA revealed a main effect of trial type [$F(2, 70) = 106.85$, *MSE* = .059, *p* < .001, $\eta_p^2 = .75$], no main effect of participant group [$F(1, 35) = 1.59$, *MSE* = .029, *p* = .22, $\eta_p^2 = .04$], and a significant interaction between trial type and group [$F(2, 70) = 4.21$, *MSE* = .059, *p* = .02, $\eta_p^2 = .11$]. Simple main effects confirmed that the AD group used significantly fewer modifiers than the control group in the common ground condition [$F(1, 35) = 11.63$, *MSE* = .053, *p* = .002, $\eta_p^2 = .25$] but not in the privileged ground or baseline conditions [both F s < 1]. The mean perspective-taking difference score for the control group was significantly larger than that of the AD group ($t(35) = -2.34$, *p* = .025, *SE* = .13).

no difference between reaction times in the congruent and neutral condition, and this was so for both the AD and the Control group.²

3.3 Hayling task performance

Data were collected from 16 patients with AD and 17 controls. Three patients with AD and one control were unavailable for testing on this task. An examination of between-group differences in reaction times reported in Table 1 reveals that the AD group was slower than the Control group in the inhibitory condition (5.21 sec versus 3.34 sec, respectively) but not in the automatic condition (1.34 sec versus 1.19 sec, respectively). An examination of between-group error rate differences revealed that the AD group produced more errors than the Control group both in the inhibitory condition (AD: 11.0 error points; Control: 5.59 error points) and in the automatic condition (AD: 3.81 error points; Control: 0.82 error points).

We fitted an LMER model to the reaction time data, with group (AD, Control) and trial type as fixed predictors, and random slopes and intercepts for participants and items³. The predictors were assigned numerical values with a range of 0.5 and a mean of 0. Results indicated that group was a significant predictor [*coefficient* = -46.70, *SE* = 11.31, *t* = -4.13, *p* < .001], such that the AD group responded more slowly than the Control group. Trial type was also a significant predictor [*coefficient* = -130.88, *SE* = 7.96, *t* = -16.44, *p* < .001], such that reaction times were faster on the automatic than on the inhibitory trials. The interaction between group and trial type was not significant [*coefficient* = -2.77, *SE* = 13.93, *t* = -.20, *p* = .84] – that is, the difference between the inhibitory and the automatic condition was similar. Simple effects indicated that there was a significant difference between groups both in the inhibitory condition [*coefficient* = -45.30, *SE* = 16.13, *t* = -2.81, *p* = .005] and the automatic condition [*coefficient* = -48.01, *SE* = 9.42, *t* = -5.10, *p* < .001].

The LMER model fitted to the error point data also indicated that group [*coefficient* = -.30, *SE* = .08, *t* = -3.62, *p* < .001] and trial type [*coefficient* = -.31, *SE* = .08, *t* = -3.81, *p* < .001] were significant predictors. Their interaction was marginally significant [*coefficient* = .27, *SE* = .15, *t* = 1.80, *p* = .07], such that there was a larger difference between the Inhibitory and the Automatic condition for the AD than for the Control group. Simple effects indicated significant differences between groups on both inhibitory trials [*coefficient* = -.44, *SE* = .15, *t* = -2.87, *p* = .004] and automatic trials [*coefficient* = -.16, *SE* = .04, *t* = -3.68, *p* < .001].⁴

3.5. Relationships between the Perspective-Taking task and Cognitive Measures

To explore the cognitive mechanisms underlying perspective-taking ability, we correlated modifier use on common ground and privileged ground trials, and the perspective-taking

²The ANOVA analyses with the factors group (AD, control) and trial type (congruent, incongruent, neutral) revealed a main effect of trial type [$F(2, 60) = 11.92$, $MSE = 948.47$, $p < .001$, $\eta_p^2 = .28$] and a main effect of group [$F(1, 30) = 9.91$, $MSE = 22018.13$, $p = .004$, $\eta_p^2 = .25$]. There was also an interaction between trial type and participant group [$F(2, 60) = 4.39$, $MSE = 948.47$, $p = .02$, $\eta_p^2 = .13$]. Simple main effects indicated that there was a difference between the three trial type conditions for the AD group [$F(2, 29) = 16.17$, $p < .001$, $\eta_p^2 = .53$] but not for the control group [$F(2, 29) = 1.05$, $p = .36$, $\eta_p^2 = .07$]. The significant simple main effects of group were further analyzed by pairwise comparisons. Confirming the presence of a Flanker effect for the AD group, reaction times were significantly slower in the incongruent condition than in both the neutral [$p < .001$] and congruent condition [$p = .002$] (and the neutral and congruent conditions were differed from each other marginally [$p = .07$]). There were no differences between conditions for the control group [all $ps > .15$].

³This model was fitted to the data from 32 participants (16 patients with AD and 16 controls) due to the missing trial level data for one control participant.

difference score with measures of cognitive functioning, verbal ability and executive functioning separately for patients and controls (see Table 2). The control group exhibited no significant correlations (among which a few marginal correlations) between supplemental measures and perspective taking ability most likely due to their near-ceiling performance on many of the tasks. For example, they were near ceiling in modifier use on common ground trials in the perspective-taking task (97%), near ceiling on the simplified Flanker task, and the Hayling task. In contrast, there were significant correlations between cognitive measures and modifier use on common ground trials, and the difference score measure, for participants in the AD group. There were no significant correlations between performance on any supplemental measure and modifier use on privileged ground trials, which may have been too difficult for speakers with AD (even though their performance did not differ from controls, see Discussion).

Briefly summarized, the AD group's modifier use on common ground trials, and also the perspective-taking difference score measure, were positively correlated with measures of general cognitive functioning and the Block Design task. In addition, modifier use on common ground trials was correlated with some executive functioning measures including response times on the Trail Making Test-A and the Flanker task. However, perspective-taking performance did not correlate with a verbal measure of inhibitory control (the Hayling task), or with performance on tests of lexical retrieval (the Boston Naming task and phonemic fluency task). Of interest, the AD group's perspective-taking difference score was significantly correlated with performance on the semantic fluency task.

Additionally, we used LMER modeling to analyze the relationships between supplemental measures and perspective taking. The purpose of these analyses was to see whether the magnitude of the relationship between each supplemental measure and modifier use was significantly stronger for the CG condition than the PG condition, and whether this relationship also varied by group (as indicated by the correlational analyses). Thus, these models had group (AD, control), trial type (common ground, privileged ground) and each of the supplemental measures examined in the correlations, as fixed predictors, and random intercepts and slopes for subjects and items, as justified by the design. The predictors were centered around the mean to reduce collinearity⁵. These models, however, did not yield any significant 3-way interactions likely because of ceiling performance of the control group, which also varied very little, on the common ground trials as well as on some of the supplemental measures. This was confirmed by fitting LMER models to the data from this

⁴A 2×2 ANOVA conducted on the reaction times with the factors trial type (automatic, inhibitory) and group (AD, Control) revealed a main effect of group [$F(1, 31) = 10.63$, $MSE = 1.59$, $p = .003$, $\eta_p^2 = .26$], a main effect of trial type [$F(1, 31) = 96.86$, $MSE = 1.54$, $p < .001$, $\eta_p^2 = .76$], and a trial type $\times$ group interaction [$F(1, 31) = 7.83$, $MSE = 1.54$, $p = .009$, $\eta_p^2 = .20$]. Simple main effects revealed that there was a significant difference between groups in the inhibitory condition [$F(1, 31) = 10.85$, $MSE = 2.65$, $p = .002$, $\eta_p^2 = .26$] but not in the automatic condition [$F < 1$]. Analyses of error points revealed main effects of trial type [$F(1, 31) = 45.66$, $MSE = 12.90$, $p < .001$, $\eta_p^2 = .60$] and group [$F(1, 31) = 17.17$, $MSE = 16.94$, $p < .001$, $\eta_p^2 = .36$] but no trial type $\times$ group interaction [$F(1, 31) = 1.88$, $MSE = 2.65$, $p = .18$, $\eta_p^2 = .06$]. Simple main effects indicated significant differences between groups on both automatic trials [$F(1, 31) = 33.13$, $MSE = 2.22$, $p < .001$, $\eta_p^2 = .52$] and inhibitory trials [$F(1, 31) = 8.74$, $MSE = 27.62$, $p = .006$, $\eta_p^2 = .22$].

⁵We aimed for the maximal random effects structure justified by our design, as recommended by Barr, Levy, Scheepers, & Tily (2013). However, these models did not converge. To deal with convergence issues, we eliminated consecutively from each model the random effects terms that seemed to explain least variance.

group alone, with trial type and each of the supplemental measures as fixed predictors – these models overfitted the data and did not allow reliable analyses (e.g., Menard, 2002).

However, identical LMER models fitted on the data of the AD group produced reliable results; these 2-way interactions in each of the models fitted on the data of the AD group are reported in Table 3. These results implied similar conclusions as the simple correlations. The one exception was the lack of a significant interaction of Trails A with trial type in the LMERs – possibly suggesting a less robust relationship between Trails A and processing for referential communication (when compared with other measures such as DRS, Block Design, the semantic portion of the Verbal Fluency task, Forward Digit Span, and the Flanker task which produced significant results in both the correlations and the LMER models).

An examination of Table 4 indicates several of the measures that significantly predicted performance for patients on common ground trials were correlated with each other. For this reason, and to better understand the contribution of those tasks most strongly correlated with perspective taking in common ground situations, we fitted two further LMER models on the common ground trial data of the AD group, with subjects and items random effects, and fixed predictors as follows: 1) Block Design and DRS; and 2) Block Design reaction times in the incongruent condition of the Flanker task. When entered together in a model, DRS [*coefficient* = .17, *SE* = .07, *z* = 2.34, *p* = .02] but not Block Design [*coefficient* = .04, *SE* = .04, *z* = .87, *p* = .38] was a significant predictor of patients' performance in the common ground condition. Thus, general cognitive ability might play a greater role than visual scanning/construction in explaining patients' common ground performance. Conversely, neither predictor was statistically significant when Block Design and Flanker incongruent RTs were entered together [Block Design: *coefficient* = .12, *SE* = .09, *z* = 1.39, *p* = .16; Flanker incongruent: *coefficient* = -.004, *SE* = .006, *z* = -.78, *p* = .44]. This suggests some overlap in cognitive mechanisms tapped by these tasks for predicting perspective taking ability – perhaps related to problem solving or visual assessment of an array of objects – may be critical for successful perspective taking in common ground situations.⁶

4.0 Discussion

The present study examined the ability of patients with AD to produce references that consider their listeners' perspective in a verbal communication task with the goal of revealing the neurocognitive mechanisms underlying this ability, which might also form the basis of communication deficits in AD. Speakers with AD made significantly more common ground errors than a matched healthy control group, referring to a particular shoe as simply "shoe" even though there was more than one shoe visible to both the speaker and the listener (note that strictly speaking, differences in performance on common ground trials may measure referencing ability relatively more than perspective-taking ability). In addition, a

⁶Note that a linear regression model with Block Design and DRS as independent variables, and proportion modifier use on common ground trials for the AD group as the dependent variable, produced different results from the corresponding LMER model: Block Design was a significant predictor [$\beta = .44$, $t = 2.18$, $p = .04$], and DRS was marginally significant [$\beta = .41$, $t = 2.06$, $p = .06$]. Given this discrepancy, the results from this analysis should be interpreted with caution. The second model produced identical results to the corresponding LMER model [Block Design: $\beta = .36$, $t = 1.37$, $p = .20$; Flanker incongruent: $\beta = -.39$, $t = -1.46$, $p = .17$].

perspective-taking difference score revealed that patients were less likely than controls to use modifiers when modifiers were necessary, but more likely than controls to use modifiers when modifiers were confusing. Patients did not produce more privileged ground errors than controls. However, patients exhibited an overall pattern of greater modifier use on common than on privileged ground trials, which suggests they had some ability to use perspective to guide their planned utterances differently and appropriately across experimental conditions. In addition, for speakers with AD, perspective-taking measures were significantly correlated with tests of general cognitive functioning, a number of executive function measures, and semantic fluency scores. Interestingly, patients' perspective-taking difference scores were significantly correlated with semantic but not with phonemic fluency scores, and also not with Boston Naming Test scores, or the Hayling Test, even though perspective taking was measured here with a verbal task. These findings suggest that perspective-taking task performance (or perhaps more specifically referencing behaviors on common ground trials), is supported by reasoning skills, the integrity of semantic memory, management of attention and response conflict, and the ability to rapidly scan visual surroundings and focus on relevant dimensions therein.

The following task analysis suggests a role for each of these cognitive mechanisms. Before speakers can plan an utterance that considers their listener's perspective, they need to correctly solve the problem of how their own view of the situation might differ. Figure 4 shows a hypothesized timeline for the cognitive skills needed to plan and produce adequate references. As implemented in the current task, when speakers are presented with an array of objects, including both a target and a privileged foil, they must first scan the array to determine which objects are present. In addition to scanning, speakers must be able to selectively attend to each object. For example, if a speaker wants to refer to a specific triangle in the presence of a star, a circle and another triangle, that speaker must have scanned, viewed and attended to both the actual target and the other triangle at minimum.

Inability to scan, view and attend to objects properly should result in an inability to produce references that include enough information for a listener to pick them out of a set. Supporting this view, patient data revealed significant correlations between speakers' scores on executive tasks that have substantial visual scanning and attention requirements, such as the Flanker task, Block Design and Trails, and their use of modifiers on common ground trials. This suggests that scanning and attending to surrounding objects is an important process and that impairment in those abilities can impair reference forms. Note that this interpretation focuses on attention-based aspects of the flanker task rather than on ability to resolve response conflict, which may be more typically associated with this task, and may also play a role in perspective taking (Wardlow, 2013).

The Block Design subtest of the WAIS-R was also significantly correlated with patients' use of modifiers on common ground trials. Scores on the Block Design subtest are strongly correlated with general performance IQ, and are sometimes used to obtain a quick approximation of nonverbal abstract conceptualization (Sattler, 1974). Viewed in this way, the significant correlation with common ground modifying rate in patients might have a similar underlying mechanism as the correlations with measures of general cognitive functioning (i.e., DRS and MMSE). Another possibility, however, is that this correlation

reflects earlier processes, similar to those underlying the correlations with Trails A and the Flanker Task, insofar as the Block Design is a timed test that requires rapid assessment of an array of designs and ability to assemble them into a coherent picture that includes all the component parts. In fact, LMER analyses supported both possibilities (i.e., Block Design was not a significant predictor of common ground trail performance when entered together with either DRS or the flanker task).

Next, speakers must conceptualize the relationships between objects. In this processing stage, the speaker will need to identify differences between common ground and privileged ground situations. This will require identifying whether the array includes pairs of objects that are the same and therefore will potentially need to be distinguished from each other. In addition, the speaker will need to consider whether any relevant object pairs are also visible to the listener (as on a common ground trial) or not (as on a privileged ground trial). Furthermore, these classifications are likely to be even more complicated in real world settings where (1) the differences between like objects can be numerous including color, size, location, and function, and (2) common ground and privileged ground status may be more difficult to determine.

To do all of these things at the same time, and quickly, speakers must have skill in a variety of cognitive domains, many of which are measured in tests of general cognitive functioning such as the Dementia Rating Scale and Mini Mental State Exam. These include awareness of surroundings, basic memory and some language support. Support for this proposal comes from the significant and positive correlations between patients' performance on the DRS and MMSE, on the one hand, and use of modifiers on common ground trials in the perspective-taking task, as well as the perspective-taking difference score, on the other.

In their theory of perspective taking, Nilsen & Fecica (2011) point out that successful perspective taking requires both the ability to mentalize and executive control abilities, which are needed to apply the understanding that the listener has a different perspective to communicative situations. The current study offers support for this theory: Significant positive correlations between the perspective-taking difference score and DRS, MMSE and semantic fluency were found. The abilities these tasks measure (general cognition and semantic knowledge) underlie the ability to make sense of the world, or mentalize (see Ahmet & Miller, 2013; but see Moran, 2013). We also found significant positive correlations between the perspective-taking difference score and Block Design, which is a measure of non-verbal IQ and seems to tap into executive control abilities, since, when entered into a regression model together with the Flanker task, the two canceled each other out, suggesting that they tap into similar mechanisms.

Finally, speakers must select for production the words with the highest activation levels and which correspond to their intended message. One can imagine a scenario by which speakers are able to conceptualize the need to (or need *not to*) use a modifier correctly, but fail to consistently incorporate that information at the right times or on the right trials. For example, even if a speaker is able to conceptualize relationships between objects and perspectives correctly, and correctly select a modifier for use, that selection may decay when speakers have to spend more cognitive resources finding the right word to describe the

target. However, neither measure of lexical retrieval (BNT nor phonemic fluency) significantly correlated with modifier use in the perspective-taking task. This finding, along with the findings discussed above, suggests that impairments in perspective taking, and likely impairments in referencing, in patients with AD arise at a relatively early processing stage, one where utterances are planned, but that precedes lexical retrieval.

In addition, the finding that the perspective-taking difference score was significantly correlated with performance on the semantic fluency task for the AD group suggests a role for the integrity of semantic representations in patients' ability to take perspective. No other verbal measure (phonemic portion of the Verbal Fluency Task, the Boston Naming Task, or the Hayling task) was correlated with perspective-taking performance. Together, these findings suggest that language impairments in AD may (at least in part) be due to a permanent semantic loss rather than to a deficit only at the level of lexical retrieval. As such, our findings support the Storage Loss account (Salmon, Thomas, Pay, Booth, Hofstetter et al., 2002) and diverge from the Retrieval Deficit account (Nebes, Martin, & Horn, 1984). By implication, the current findings might also ultimately support the hypothesis that perspective-taking deficits in AD reflect damage to the frontal lobes.

The neural regions implicated in performance on the perspective-taking task have not been investigated to date. Relationships between the perspective-taking task and neuropsychological measures can shed light on the neural mechanisms possibly underlying perspective taking. Current data suggest that a constellation of regions of interest (ROIs) that might underlie perspective taking would be those associated with the Flanker task, TMT-A and Block Design, and possibly semantic fluency. Specifically, neuroimaging studies suggest that executive control of attention and conflict management in tasks such as the Flanker task rely on anterior cingulate cortex (ACC) and the medial frontal lobes (Bush, Luu, & Posner, 2000; Fan, McCandliss, Flombaum, Thomas, & Posner, 2001; MacDonald, Cohen, Stenger, & Carter, 2000). The ACC is also implicated in visual search and visual attention (Hao, Li & Li, 2005), which may be relevant to performance on the Trails A and Block Design, and the ACC along with the left inferior frontal gyrus (LIFG) and temporal cortex (Robinson, Shallice, Bozzali & Cipolotti, 2012), may also be relevant to performance on semantic fluency.

In contrast, because we did not observe significant relationships between perspective taking or referencing ability and the BNT, phonemic fluency, TMT-B and the Hayling test, brain regions related to performance on these tasks may not be crucial for the task as measured here. For example, the BNT has been associated with the left parahippocampal gyrus (e.g., Petersen et al, 2000). Similarly, response initiation in the Hayling task has been associated with the left inferior frontal gyrus and response inhibition is associated with left prefrontal regions such as Brodmann Area (BA) 9, BA10 and BA45 (Collette et al, 2001). Lesion studies suggest that phonemic fluency is supported by left inferior frontal gyrus (Robinson, Shallice, Bozzali & Cipolotti, 2012). Furthermore, lesion and imaging studies suggest that TMT-B does not strictly measure frontal lobe functioning (Demakis, 2004), but rather also recruits non-frontal regions such as the left middle and superior temporal gyrus (Moll, de Oliveira-Souza, Moll, Bramati, & Andreiuolo, 2002; Oosterman et al, 2010; Zakzanis, Mraz, & Graham, 2005).

Together, these data suggest that ACC, medial frontal lobes (and possibly inferior temporal cortex), but not the left middle temporal gyrus, superior temporal gyrus, left parahippocampal gyrus or left prefrontal cortex, may support perspective-taking performance. The LIFG has been implicated both in tasks that were, or were not, significantly correlated with perspective taking; thus, it is not clear what predictions could be made about a possible role for the LIFG in communicative perspective taking. Furthermore, these speculations suggest that communicative perspective-taking task performance is not supported diffusely by the entire brain (as possibly suggested by the fact that AD ultimately affects the entire brain and correlations with DRS and MMSE).

4.1. Conclusions and future directions

The current study revealed deficits in patients with AD even though the perspective-taking task was designed to reduce the cognitive burden of producing a reference (in comparison to everyday communicative situations) in that only four objects were presented in each array and the object that was privileged to the speaker was clearly marked. Yet, speakers with AD still performed significantly worse than controls in that they often failed to provide adequate information for a listener to be able to pick out an intended target from related surrounding objects.

The performance of the control group was not revealing about possible relationships between perspective taking and underlying cognitive mechanisms. This may have been caused by the need to simplify the perspective-taking task itself, as well as some of the cognitive measures (in particular the flanker task) to make them suitable for patients in the AD group. Thus, it is perhaps not surprising that few correlations were found between the perspective taking task and cognitive measures in the control group. For example, one of the defining features of the control group was their near ceiling performance on the DRS and MMSE. Additionally, the control group performed exceptionally well on our simplified versions of the Flanker task, and were at ceiling levels of performance on common ground trials in the perspective-taking task. That said, the control group was not at ceiling performance on privileged ground trials, and it could therefore have been expected that some correlations would be observed (given that we measured ability in a broad range of cognitive functions), and previous observations of significant correlations in unimpaired younger adults' between perspective taking performance and the Flanker task and Digit Span (Wardlow, 2013). Alternatively, cognitive mechanisms identified here may be more specific to referential communication than to perspective taking; further research with different variants of the perspective-taking task may distinguish between these possibilities.

Some remaining questions of interest are why measures of inhibitory control (e.g., the Hayling task) did not consistently correlate with perspective-taking performance, and why the AD group did not differ from the Control group on privileged ground trials specifically, where speakers might need to inhibit their own perspective to support accurate modifier use. For a number of reasons, we suggest that this finding should not be interpreted as "intact performance" for patients on privileged ground trials. On a privileged ground trial, producing a perspective-adjusted reference requires speakers to *avoid* using a modifier (saying "the shoe" instead of "the small shoe" because the listener can see only one shoe).

However, modifiers might not be produced in this context for at least two different reasons including (a) successful accommodation of perspective differences as described; or, (b) a failure to register the presence of possibly relevant surrounding objects. Indeed, this second scenario was common in patients' performance on common ground trials on which they failed to account for surrounding objects on 30% of trials (as measured through their failure to include information – a modifier – that would uniquely distinguish the object they intended from the two in the display). Given this possibility, it becomes impossible to determine with confidence whether any given non-modified reference (“the shoe”) resulted from success at accommodating perspective differences, or from a failure to account for any of the other potential referents. This might explain why the AD group did not differ from the Control group in their use of modifiers in privileged ground, and consequently why performance on this measure also did not reveal any significant correlations with the other measures.

Future research may reveal ways to better understand patients' abilities to cope with privileged ground contexts to better assess the components underlying perspective taking as opposed to reference production (for discussion of this distinction see Keysar, 1997). The current manipulation of privileged ground may have been considerably more challenging for patients with AD than for controls, and therefore did not reveal the cognitive mechanisms underlying this type of perspective taking ability (but, as noted above, patient's utterances did exhibit sensitivity to conditions, implying some ability to adjust perspective in privileged ground). Additionally, the current study provides some possible insights into causes of communicative breakdown during referential communication between patients and caregivers. Adjustments to the task that might improve communication could include reducing the number of objects in an array, or rearranging the objects so that like objects are next to each other. Of further interest might be to examine if more practice with the task might improve performance and communication. That said, the impairments revealed in the present study suggested that very basic cognitive abilities that affect utterance planning in its earliest stages may underlie communicative impairments – and, in this respect there might be serious limitations on the extent to which perspective taking could improve with practice.

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Highlights

- Successful communication requires perspective taking (PT).
- Impairments in PT can reveal underlying cognitive mechanisms.
- The effect of Alzheimer's Disease on PT ability was assessed.
- PT correlated with cognitive and executive functioning and semantic fluency.
- Perspective taking impairments in AD likely occur at a preverbal processing stage.

Figure 1.
Example Experimental Display.

Figure 2.
Description of Common Ground and Privileged Ground trials.

Figure 3.
Percentage of Utterances that Included Modifiers, by Contrast Type and Group.

Figure 4.
Proposed Processes for Producing a Reference.

Table 1

Means, standard deviations and comparisons for all participants' characteristics

Characteristic	AD		Control		Group Difference	
	M	SD	M	SD	t-value	p-value
Age	78.26	(7.70)	79.00	(5.25)	.34	.74
Education	16.16	(2.87)	17.39	(2.97)	1.28	.21
% Females	32%		44%			
DRS	113.26	(10.19)	140.56	(2.60)	11.29	<.001
MMSE	21.95	(4.25)	29.17	(.92)	7.23	<.001
Block Design	28.05	(12.51)	49.33 ^a	(7.48)	5.81 ^a	<.001
Boston Naming Test	21.00	(5.04)	28.61	(1.98)	6.10	<.001
Verbal fluency total correct	54.11 ^b	(16.63)	107.89	(22.24)	8.22 ^b	<.001
Verbal fluency total errors	11.22 ^b	(8.99)	5.56	(3.17)	2.52 ^b	<.05
Verbal fluency Semantic correct	20.21	(8.11)	56.33 ^c	(15.66)	8.12 ^c	<.001
Verbal fluency Phonetic correct	31.47	(13.71)	53.67 ^c	(9.18)	4.39 ^c	<.001
Trail Making A RT sec	66.05	(32.92)	33.78	(16.09)	3.82	.001
Trail Making B RT sec	211.75 ^d	(78.46)	71.56	(24.86)	6.85 ^d	<.001
Digits FWD Length	5.89	(1.10)	7.00	(1.19)	2.94	<.01
Digits BWD Length	3.53	(.96)	5.17	(1.20)	4.60	<.001
Flanker Congruent RT ms	766 ^e	(171)	607 ^f	(140)	2.88 ^{e,f}	<.01
Flanker Incongruent RT ms	805 ^e	(168)	614 ^f	(117)	3.72 ^{e,f}	.001
Flanker Neutral RT ms	745 ^e	(176)	599 ^f	(121)	2.74 ^{e,f}	.01
Flanker Congruent Error	.05 ^e	(.10)	.02 ^f	(.03)	1.04 ^{e,f}	.31
Flanker Incongruent Error	.05 ^e	(.09)	.00 ^f	(.00)	2.28 ^{e,f}	<.05
Flanker Neutral Error	.04 ^e	(.09)	.02 ^f	(.03)	1.05 ^{e,f}	.31
Hayling Automatic RT sec	1.35 ^g	(.31)	1.19 ^h	(.92)	.67 ^{g,h}	.51
Hayling Inhibitory RT sec	5.21 ^g	(2.06)	3.34 ^h	(1.08)	3.29 ^{g,h}	<.01
Hayling Automatic Error	3.81 ^g	(1.87)	.82 ^h	(1.02)	5.66 ^{g,h}	<.001
Hayling Inhibitory Error	11.00 ^g	(6.01)	5.59 ^h	(4.43)	2.96 ^{g,h}	<.01

- $a_{NNC} = 15$
- $b_{NAD} = 18$
- $c_{NNC} = 9$
- $d_{NAD} = 17$
- $e_{NAD} = 16$
- $f_{NNC} = 16$
- $g_{NAD} = 16$
- $h_{NNC} = 17$

Table 2

Correlations between modifier use on perspective taking trials and measures of general cognitive functioning, verbal abilities and executive function for the AD and Control group.

	AD Group			Control Group		
	Common Ground	Privileged Ground	Common-Privileged	Common Ground	Privileged Ground	Common-Privileged
Age	.06	-.38	.41 [†]	-.08	.31	-.32
Education	-.002	-.14	.13	.13	.12	-.11
General Cognitive Function						
DRS Total	.65**	-.06	.60**	.00	.08	-.08
DRS: Attention	.46	.26	.15	.42 [†]	-.18	.24
DRS: Initiation	.25	-.07	.27	.19	.14	-.11
DRS: Construction	.45*	-.14	.52*	-.29	.17	-.21
DRS: Conceptualization	.56**	-.03	.49*	-.27	.18	-.22
DRS: Memory	.36	-.08	.39 [†]	.36	-.30	.35
MMSE	.58	.07	.39*	-.17	-.03	.01
Block Design	.66** ^a	.01 ^a	.55** ^a	.26	.43	-.38
Verbal Ability						
Boston Naming	-.13	.009	-.12	.03	.00	.00
Verbal Fluency - Semantic	.24 ^b	-.28 ^b	.47* ^b	.44 ^c	.20 ^c	-.12 ^c
Verbal Fluency - Phonetic	.12 ^b	.02 ^b	.08 ^b	.02 ^c	.13 ^c	-.13 ^c
Executive Function						
Trail Making A RT	-.60**	-.37	-.16	.15	.23	.39
Trail Making B RT	-.33 ^d	.20 ^d	-.46* ^d	-.36	.27	.41 [†]
Digits FWD Length	-.30	.12	-.38	.09	.26	.34
Digits BWD Length	.19	-.07	.37	.24	.02	-.25
Flanker Congruent RT	-.60** ^e	-.07 ^e	-.43* ^e	-.34 ^f	.13 ^f	-.28 ^f
Flanker Incongruent RT	-.61** ^e	-.12 ^e	-.39 ^e	-.42* ^f	-.19 ^f	-.33 ^f
Flanker Neutral RT	-.60** ^e	-.14 ^e	-.36 ^e	-.40 ^f	.42* ^f	-.32 ^f

	AD Group				Control Group			
	Common Ground	Privileged Ground	Common-Privileged	Common Ground	Privileged Ground	Common-Privileged	Common-Privileged	
Hayling Automatic RT	-.16 ^g	-.12 ^g	-.02 ^g	.18 ^h	.02 ^h	.00 ^h	.00 ^h	
Hayling Inhibitory RT	.10 ^g	-.08 ^g	.16 ^g	-.44 ^{†h}	.13 ^h	-.19 ^h	-.19 ^h	
Hayling Automatic Errors	-.45 ^{†g}	.00 ^g	-.35 ^g	.07 ^h	-.19 ^h	.19 ^h	.19 ^h	
Hayling Inhibitory Errors	-.39 ^g	-.18 ^g	-.13 ^g	.28 ^h	.42 ^{†h}	-.38 ^h	-.38 ^h	

**
 $p < .01$,

*
 $p < .05$,

†
 $p < .1$

^a_{NNC} = 15

^b_{NAD} = 18

^c_{NNC} = 9

^d_{NAD} = 17

^e_{NAD} = 16

^f_{NNC} = 16

^g_{NAD} = 16

^h_{NNC} = 17

Table 3

Interactions in LMER models investigating modifier use on the perspective taking task and measures of general cognitive functioning, verbal abilities and executive function for the AD group.

Analysis	Coefficient	SE	z	p
Trial Type*DRS total	-.17	.06	-2.69	.007**
Trial Type*MMSE	-.26	.14	-1.85	.064†
Trial Type*BNT	.06	.14	.46	.644
Trial Type*Block Design	-.15	.04	-3.51	<.001***
Trial Type*Verbal Fluency – Semantic	-.15	.07	-1.99	.046*
Trial Type*Verbal Fluency – Phonetic	.01	.05	.21	.832
Trial Type*Trail Making A RT ^a	.02	.02	1.13	.258
Trial Type*Trail Making B RT ^a	.02	.009	1.74	.081†
Trial Type*Digits FWD Length	1.24	.56	2.24	.025*
Trial Type*Digits BWD Length	-.24	.67	-.35	.723
Trial Type*Flanker Incongr.	.008	.004	2.02	.044*
Trial Type*Hayling Inhib. RT ^a	-.43	.51	-.84	.401

Note: All models had (perspective-taking) trial type, each of the supplemental measures, and their interaction, as fixed predictors. Predictors were centered around the mean.

^aThe model with a maximal random effects structure did not converge. To deal with convergence issues, we eliminated consecutively from each model the random effects terms that seemed to explain least variance.

Table 4
Person bivariate correlations between supplementary task scores for both participant groups.

	AD Group					Control Group						
	DRS	MMSE	Block Design	TMT A RT	Flanker Cong. RT	Flanker Inc. RT	DRS	MMSE	Block Design	TMT A RT	Flanker Cong. RT	Flanker Inc. RT
MMSE	.54*						.11					
Block Design	.55*	.28					.63*	.17				
TMT A RT	-.33	-.09	-.69**				.22	.30	.22			
Flanker	-.58*	-.48 [†]	-.66**	.34			.28	.00	.14	.08		
Flanker Inc	-.59*	-.43	-.63**	.42	.95**		.17	.10	.05	.00	.97**	
Flanker	-.52*	-.41	-.63**	.44 [†]	.96**	.95**	.20	.00	.06	.00	.98**	.98**

Note: DRS = the Dementia Rating Scale (Mattis, 1988); MMSE = the Mini Mental State Examination (Folstein et al., 1975); TMT A = Trail Making Test A; Cong. = Congruent condition; Incong. = Incongruent condition.

** p < .01;
* p < .05;
[†] p < .1