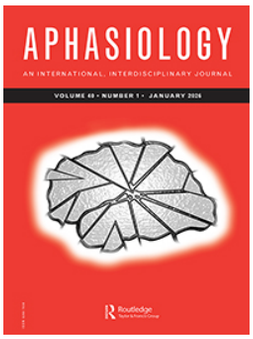

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Enhanced clinical evaluation of Alzheimer disease through rapid automatized naming of emotional pictures

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ABSTRACT

Purpose: Naming tests are commonly incorporated as short versions into clinical evaluation of Alzheimer disease (AD), but evidence suggests they may overestimate semantic abilities. This study investigated whether a more challenging naming task could distinguish cognitively healthy individuals from those with amnestic mild cognitive impairment (aMCI) and mild AD, while more effectively capturing lexical-semantic deficits.

Method: In this cross-sectionally study, 15 aMCI patients, 15 mild AD patients, and 20 cognitively healthy controls completed a rapid automatized naming (RAN) task using emotionally balanced object and action pictures. Regression analyses and receiver operating characteristic (ROC) curves were used to evaluate diagnostic accuracy and identify influencing factors.

Results: Controls significantly outperformed aMCI and AD groups in response times and naming accuracy (all p-values <0.001). Negative pictures elicited slower responses and higher error rates in controls. While the "negative delay" effect was attenuated in patient groups, negative stimuli remained cognitively demanding, as indicated by increased errors. Emotional valence enhanced naming performance for action pictures in the control group, a pattern that diminished or was absent in the patient groups. Regression analyses showed significant associations between response times/error rates and group membership (both p-values <0.001), independent of age, sex, education, anxiety, and depression. ROC analysis revealed moderate diagnostic accuracy for classifying mild AD (AUC of 0.907 for response times; AUC of 0.861 for error rates), but not for aMCI.

Conclusion: The RAN task effectively identifies early stages of AD and naming impairments across different stages of cognitive

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decline. The inhibitory effect of negative valence on lexical retrieval underscores the importance of incorporating emotional valence into naming assessments by further considering emotional reactivity (arousal) and different word classes.

Introduction

The aging of our global population is driving a rise in dementia prevalence, posing significant challenges for healthcare systems (Li et al., 2022; Steinmetz et al., 2024). Alzheimer disease (AD), the leading cause of dementia, affects about 1 in 9 individuals aged 65 and older (Alzheimer's Association, 2023).

In early AD, neurofibrillary pathology in the medial temporal and hippocampal regions leads to degradation (Braak & Braak, 1991), contributing to semantic memory impairment (Balthazar et al., 2008; Chenery et al., 1996; Noroozian et al., 2018; Venneri et al., 2019). These deficits, such as word-finding difficulties, are a hallmark feature of AD (Kavé & Goral, 2018; Martínez-Nicolás et al., 2019; Salehi et al., 2017), evident even in the prodromal stage of the disease (Joubert et al., 2021), known as amnestic mild cognitive impairment (aMCI; Petersen et al., 2014).

Word retrieval deficits in AD are linked to semantic breakdown, which may result from impaired access to or loss of semantic representations (Mårdh et al., 2013). Given the similarity of semantic deficits across modalities, there is a broad consensus that AD progression involves the degradation of semantic storage rather than problems accessing information from semantic memory (Hodges & Patterson, 1995; Hodges et al., 1992; Huff et al., 1986; Mårdh et al., 2013; Verma & Howard, 2012). These difficulties impair the ability to communicate, thereby affecting mental and emotional well-being (DiBenedetti et al., 2020; Lima et al., 2020; Palmer et al., 2019).

The role of emotions on word retrieval in AD

Emotional attributes enhance semantic memory retrieval compared to neutral targets (Kissler & Herbert, 2013; Rainer et al., 2022; Zeelenberg et al., 2006). However, the effects of positive and negative valence on word processing remain uncertain (Kauschke et al., 2019). Kauschke et al. (2019) discussed three explanatory approaches: the "positivity bias", which represents a processing advantage for positive information; the "negativity bias", indicating a preference for negative information; and the "negative delay", where negative stimuli require more attention and emotion regulation, leading to longer reaction times and more errors. These approaches are supported by a highly heterogeneous body of findings primarily attributed to methodological differences (see Kauschke et al., 2019, for a review).

In AD, semantic memory breakdown is a key symptom, and emotional words may provide insights into the severity of cognitive decline. Emotional words like "joy" or "fear" are linked to brain regions like the amygdala and hippocampus, both critical for emotional enhancement in semantic memory (Mistridis et al., 2013). Notably, atrophy of the amygdala in AD is comparable to that of the hippocampus and correlates with the severity of

cognitive impairment (Mistridis et al., 2013; Poulin et al., 2011). As both of these brain regions play essential roles in processing emotional content, the atrophy they experience in AD may alter the way emotional words are processed, leading to potential impairments in individuals with AD (da Silva et al., 2021).

Studies suggest that decoding negative emotions may be more impaired than positive ones in AD, though this may depend on disease severity and emotional context (e.g., anger may be more easily recognized than sadness due to higher levels of excitement; da Silva et al., 2021). Emotional content as a conceptual attribute (Hinojosa et al., 2020) may reveal specific impairments in word retrieval that neutral words do not, offering deeper insights into semantic decline in AD.

The emotional content of words is processed both at the lexical and post-lexical levels (Hinojosa et al., 2020; Palazova et al., 2011) and interacts with other semantic variables, like concreteness, contributing to the semantic richness of words (Hinojosa et al., 2020). For instance, Moseley et al. (2011) found that the meanings of abstract words are often acquired through their association with emotional expressions. This suggests that emotions impact abstract words more than concrete ones, leading to faster processing of abstract words compared to concrete words (Vigliocco et al., 2013).

The noun-verb dichotomy in lexical retrieval in AD

Understanding the factors influencing semantic memory retrieval is crucial for the clinical evaluation of AD. Differences in noun-verb processing are well-documented, with some individuals showing greater impairment in verb or noun retrieval (Mätzig et al., 2009). While nouns are primarily associated with the temporal lobe and verbs with frontal areas, recent studies indicate overlapping neural regions for both (Faroqi-Shah et al., 2018). Early-stage AD primarily affects temporal regions (Braak & Braak, 1991), suggesting nouns may be more vulnerable than verbs. However, the evidence remains inconsistent, with some studies reporting no clear selective preservation of verbs (Cappa et al., 1998; Druks et al., 2006; Lukic et al., 2021; Masterson et al., 2007; Williams et al., 2021). As Baker (2015) noted, this underscores the need to consider aspects beyond a strict noun-verb dichotomy, such as language and task type. One such factor is "category conversion", a phenomenon in which a word can shift its grammatical category without morphological change, as seen in languages like English or German (e.g., *essen* "eat" in German as noun or verb). This ability depends on the lexical semantics of the word and the elicitation method used. In naming tasks, for example, category conversion may be more restricted compared to sentence production tasks, as the picture provides a clear visual reference to the object or action (Baker, 2015).

The noun-verb distinction is often discussed in terms of their distinct processing demands (Druks et al., 2006). Verbs are grammatically more complex than nouns and have a less elaborate semantic organization with fewer shared semantic features (Druks et al., 2006; Mätzig et al., 2009). As noted by Tyler et al. (2004), verbs require more neural resources due to their inflectional morphology. In German, the "fragmentation" of verbs – where they are split into multiple morphological units (e.g., separable verbs like *abholen* "to pick up") – adds additional complexity (Tyler et al., 2004). While verbs can have various inflections (e.g., *abholen, geholt, holte*), nouns are only inflected with a plural marker. The increased

activation in the left inferior frontal gyrus (LIFG) may reflect selection processes among the inflected forms of verbs. In contrast, when neither nouns nor verbs are inflected, they seem to activate the same neural system equally (Tyler et al., 2004).

In picture naming tasks, matching nouns and verbs is challenging due to differences in psycholinguistic variables such as word frequency, concreteness, imageability, and visual complexity. For instance, concrete verbs are generally less imageable than concrete nouns, and action pictures tend to be more visually complex than object pictures (Druks et al., 2006). Furthermore, Palazova et al. (2011) demonstrated that the emotional content of words affects word retrieval differently across grammatical classes. While nouns often represent more concrete objects or concepts, verbs typically denote actions, making them contextually and emotionally more complex. Additionally, the emotional processing of nouns seems to be context-dependent, shaped by their interaction with other word classes. This can result in more superficial emotional processing when nouns are considered alongside other word classes (Palazova et al., 2011).

Integrating processing speed in assessing naming abilities in AD

Picture naming tasks, like the Boston Naming Test (BNT; Kaplan et al., 2001), are often used as part of comprehensive test batteries like the Consortium to Establish a Registry for Alzheimer's Disease (CERAD; Morris et al., 1989) to assess object naming and to aid in staging AD severity. However, short versions of the BNT have their limitations, potentially leading to overestimation of semantic abilities (Katsumata et al., 2015). The CERAD BNT-15, for example, includes too few items across semantic categories and lacks differentiation of error types (Harry & Crowe, 2014). Additionally, these tasks fail to account for grammatical classes. Simple naming tasks like the CERAD BNT-15 often miss such distinctions and therefore often fail to detect subtle or selective semantic impairments. As a result, the extent of semantic breakdown may be masked, and patients may appear unimpaired despite underlying deficits.

In contrast, Rapid Automatized Naming (RAN) tasks require quick naming of visually presented items (e.g., pictures) under timed conditions, measuring processing speed and executive control in language access (Mazur-Mosiewicz & Davis, 2011). This makes RAN tasks distinct from traditional naming tests, which primarily assess the ability to retrieve and produce words. RAN engages executive control processes, including attention, sequential response management, and conflict resolution, all of which are necessary for efficient lexical retrieval under time constraints. These processes are particularly relevant in cognitive conditions like AD, where executive functions are commonly impaired (e.g., Junquera et al., 2020).

RAN tasks can be conducted in two formats. The serial format, where visually presented items appear in a continuous sequence in rows or columns, and the discrete format, where targets are presented as separate individual items.

These tasks have shown promise in detecting early cognitive decline in aMCI and AD (Jacobson et al., 2004; Wu et al., 2022). By combining processing speed, executive control, and semantic abilities, RAN offers a more comprehensive evaluation of communication-related deficits, identifying subtle impairments that traditional naming tasks often miss.

Motivation of the study

Word retrieval deficits are among the earliest signs of AD and can hinder effective communication in daily life.

Understanding semantic impairments in AD requires an integrative approach that combines cognitive and linguistic perspectives. Emotions, access to and retrieval from semantic memory, and processing speed are crucial for communication, making their interplay worth examining. The valence hypothesis suggests that emotional words are processed differently (Kauschke et al., 2019), with AD-related atrophy in emotion-related brain regions impacting retrieval (da Silva et al., 2021). Neural degradation in AD further disrupts lexical-semantic connections, making verbs – less interconnected than nouns – particularly vulnerable. Additionally, RAN tasks provide insights into lexical access speed, revealing executive control deficits that further impair naming.

Based on these theoretical perspectives, we developed a novel approach to assess word retrieval by incorporating word class (nouns, verbs), emotional valence (positive, negative, neutral), and processing speed. Our goal was to create a naming task to detect early AD-specific changes and distinguish between cognitively healthy controls, aMCI, and mild AD. This study aims to deepen our understanding of how emotional content, word class, and processing speed interact in AD-related semantic memory decline by measuring naming performance through naming latency (in milliseconds) and error rates. To achieve this, we tested the following hypotheses:

[Reduced negative delay:] The prevailing literature suggests that negative stimuli require more attentional resources. Cognitive decline in aMCI and AD is expected to reduce this effect, leading to a smaller discrepancy in response times (RTs) between negative and positive/neutral stimuli. We also expect error rates for negative stimuli to be similar to positive/neutral stimuli in the patient groups, particularly in AD.

[Noun-verb dichotomy:] Despite brain atrophy affecting regions crucial for both word classes in the early stages of AD, we expect faster and more accurate naming of object pictures (nouns) over action pictures (verbs) due to higher processing demands for verbs.

[Slowed processing speed:] We anticipate replicating the finding of slowed processing speed due to AD-related atrophy in the brain. Consequently, we expect poorer naming performance in the aMCI and AD groups compared to the control group. In line with the progressive nature of cognitive decline, we assume greater impairment in the aMCI group relative to controls, but better performance than in the AD group.

Method

Ethics approval and consent to participate

The study was approved by the local Ethics Committee (Ethics Commission Salzburg/Ethikkommission Land Salzburg; number 1044/2021) and was conducted in accordance with the ethical principles specified in the Declaration of Helsinki. Written informed consent was obtained from all participants.

Sample and recruitment

Data were collected between April 2022 and December 2023 from 30 cognitively impaired patients (15 aMCI, 15 mild AD) and 20 cognitively healthy controls. Patients were recruited in the memory outpatient clinic of the Department of Neurology, Christian Doppler University Hospital, Salzburg after neuropsychological and neurological examination. Cognitively healthy controls were recruited through personal acquisition and during the follow-up examination of a large epidemiological study sample (the Paracelsus 10.000 study, Frey et al., 2023).

Patients were selected, if they met the following inclusion criteria: (1) There was a diagnosed neurocognitive disorder: *for aMCI*: according to the criteria of Winblad et al. (2004); for *mild AD*: according to the criteria of McKhann et al. (2011); for both considering the CERAD total score and Mini Mental State Examination (MMSE; Folstein et al., 1975) with a cut-off ≥19, and additional neuropsychological tests if necessary, (2) (Austrian) German as a first language, (3) adequately corrected hearing and vision. Exclusion criteria included brain surgery, other neurological or psychiatric conditions, and sedating medications. Cognitively healthy controls had CERAD total scores > 85.1 (Chandler et al., 2005) and no history of neurological or psychiatric conditions.

The demographic characteristics and results of significance tests across the groups are displayed in Table 1. Cognitively healthy controls were significantly younger than individuals with aMCI and mild AD, with no significant age difference between aMCI and mild AD groups. Pairwise group comparisons indicated that aMCI had significantly lower CERAD plus scores than controls, while patients with mild AD had lower scores than individuals with aMCI. In terms of education, controls had significantly higher levels than patients with aMCI and mild AD. No significant differences were found between aMCI and mild AD. Furthermore, significant differences in HADS-D scores showed that patients with mild AD reported higher levels of depression compared to controls.

Table 1. Demographic characteristics of the study participants.

		CHC	aMCI	AD	Kruskal Wallis test	Dunn's test, p-values (effect size)		
Female/male ratio		11/9	5/10	7/8	CHC vs. aMCI vs. AD	CHC vs. aMCI	CHC vs. AD	aMCI vs. AD
Mean age (SD)		67.95 (4.54)	72.93 (6.77)	75.40 (5.72)	H(2) = 13.05, p = 0.001	p = 0.042* (0.392)	p = 0.001*** (0.590)	p = 0.308 (0.189)
CERAD total score (SD)		101.47 (5.55)	83.85 (7.9)	64.63 (7.48)	H(2) = 41.14, p < 0.001	p < 0.001*** (0.791)	p < 0.000*** (0.845)	p < 0.000*** (0.821)
Mean education (SD)		12.25 (2.31)	10.87 (2.64)	10.53 (2.48)	H(2) = 8.15, p = 0.016	p = 0.049* (0.390)	p = 0.049* (0.409)	p = 0.907 (0.025)
HADS-D	anxiety (SD)	3.42 (2.32)	5.40 (3.18)	6.07 (3.85)	H(2) = 6.07, p = 0.048	p = 0.118 (0.321)	p = 0.094 (0.371)	p = 0.582 (0.106)
	depression (SD)	2.53 (2.14)	4.20 (2.73)	5.79 (3.60)	H(2) = 8.41, p = 0.014	p = 0.124 (0.318)	p = 0.022* (0.463)	p = 0.254 (0.216)

Note. CHC = cognitively healthy control group; aMCI = group of individuals with amnestic mild cognitive impairment; AD = group with individuals with mild Alzheimer disease; SD = standard deviation; * p < 0.05, ** p < 0.01, *** p < 0.001

Cognitive testing

Participants completed the CERAD neuropsychological test battery (Morris et al., 1989) and, if necessary, additional tests to assess verbal memory and attention using the *Verbaler Lern- und Merkfähigkeitstest* (VLMT; Helmstaedter et al., 2001) and the *Test for Attentional Performance* battery (TAP; Zimmermann & Fimm, 2012). The German version of the Hospital Anxiety and Depression Scale (HADS-D, Hermann-Lingen et al., 2018) was administered to screen for anxiety and depression, potentially influencing cognitive performance. The cognitive profiles of the aMCI and mild AD patients are provided in Appendix A.

Materials

For the stimulus set 45 object pictures (nouns) and 45 action pictures (verbs) were sourced from Shutterstock (https://www.shutterstock.com/de/) and Pixabay (https://pixabay.com/). The pictures were realistic photographs aimed at enhancing visual processing (Zannino et al., 2010). They were chosen based on concreteness, emotional valence (positive, negative, neutral) and imageability using the normative ratings from the *Automatically Generated Affective Norms for German Lemmas* (Köper & Walde, 2016). To facilitate the accuracy of word production, two-syllable words with a predominant focus on a trochaic stress pattern were selected (Howard & Smith, 2002), aligning with German language characteristics (Domahs et al., 2008). A list of pictures was created, comprising 15 positive, 15 negative, and 15 neutral pictures for object naming and 15 positive, 15 negative, and 15 neutral pictures for action naming. The stimuli were organized into two blocks: one for naming object pictures and another for naming action pictures.

Non-parametric t-tests were conducted to examine differences between object and action picture naming concerning psycholinguistic variables. Significant differences were found in concreteness [$W = 1446$, $p < 0.001$] and imageability [$W = 1172$, $p < 0.001$], with nouns rated as more concrete and more imageable than verbs.

As intended, there was a significant difference in emotional valence ratings among positive, negative, and neutral pictures ($H(2) = 54.74$, $p < 0.001$). In addition, a significant discrepancy was found in arousal levels ($H(2) = 26.63$, $p < 0.001$). Pairwise comparisons using Dunn's test indicated no significant difference in ratings between neutral and positive pictures ($z = -1.21$, $p = 0.228$). However, arousal levels were significantly lower for neutral ($z = -5.05$, $p < 0.001$) and positive ($z = 3.60$, $p < 0.001$) compared to negative pictures. No significant differences were found in concreteness or imageability across the emotional pictures (all p-values >0.151).

A list of stimuli, along with their psycholinguistic properties and descriptive statistics, is provided in Appendix B.

Procedure

A RAN paradigm was created using the Presentation® software (Version 23.0, Neurobehavioral Systems, Inc. Berkeley, CA, www.neurobs.com). Participants were instructed to name 90 pictures as quickly and accurately as possible. Pictures were presented sequentially in two blocks: 45 object and 45 action pictures. Since object and

action naming place different demands on processing (Faroqi-Shah et al., 2018), the stimuli were not counterbalanced. Items within each block were randomized for each participant. Pictures were presented sequentially using a discrete RAN format. This approach is more adept at reflecting the speed of lexical access compared to serial presentation, where the pictures to be named are presented simultaneously in an array (de Jong, 2011). Moreover, discrete presentation enables a more item-specific interpretation by mitigating potential influences from preceding or subsequent items.

Before each block, participants were trained using six pictures not included in the experimental material. If they responded incorrectly, the correct response was provided, along with additional clarification of the instructions. No feedback was given during the experimental trials.

For object picture naming, participants were instructed as follows: *"Pictures of objects appear in sequence on this screen. Name the pictures as quickly and correctly as possible. Please use only one word for each. Try to answer directly and avoid `hmm`, `ahm´ or similar statements, as these falsify the measurement result"*.

For action picture naming, participants were instructed as follows: *"Pictures of actions appear in sequence on this screen. Say what the person or people are doing as quickly and correctly as possible. Please use only one word for each, by choosing the basic form of the verb. For example, a picture that shows someone cycling would be correct: `cycling´ and not, `he is cycling`. Try to answer directly and avoid `hmm`, `ahm´ or similar statements, as these falsify the measurement result"*.

Each stimulus item was presented individually in the center of the laptop screen for up to 10,000 ms or until a verbal response, with a 2000-ms blank screen between items. Naming latencies were recorded using a voice key.

Data analysis

Response times (RTs) and accuracy were measured for each item and averaged across conditions (word class, emotional valence) for each participant. Items correctly identified by fewer than 75% of cognitively healthy controls were excluded ($n = 11$: 1 negative noun, 3 positive verbs, 3 negative verbs, 4 neutral verbs), resulting in 44 object and 35 action pictures for the word class analysis. Emotional valence was classified based on the normative ratings from Köper and Schulte im Walde (2016). Words with ratings > 6.0 were categorized as positive, < 4.0 as negative, and between > 4.3 and < 5.7 as neutral. A gap between valence categories was introduced to strengthen the valence effect and ensure a clearer assignment to the respective category. This resulted in 19 positive pictures (11 nouns, 8 verbs), 19 negative pictures (12 nouns, 7 verbs), and 25 neutral pictures (15 nouns, 10 verbs).

Naming latencies. RTs were measured as the time in milliseconds (ms) between picture presentation and the first complete naming attempt. RTs were automatically recorded using Presentation® software and verified or manually adjusted with Praat (Boersma & Weenink, 1992–2022) to correct for early or late detections by the voice key. RTs for naming errors or missing responses were excluded from analysis.

Naming accuracy. Correct responses matched the target word or an acceptable alternative (e.g., synonyms). Incorrect responses, labelled as *naming errors*, included semantically related errors, such as substitutions (e.g., "melon" for "pumpkin") or

superordinate terms (e.g., "music instrument" for "harp"), semantically unrelated errors (e.g., "sword" for "whip"), visual errors (e.g., "fan" for "shell"), and rule-breaking errors (e.g., sentences or incorrect word categories like "cold" for "freeze"). Responses categorized as *missings* included technical errors or unintended vocalizations such as lip smacking, unintended comments or verbal placeholders like "erm".

Due to the small sample size and increased response variability, outliers were retained to capture individual differences within each group, as they can provide additional insights beyond the average performance (LaPlume et al., 2021). Descriptive statistics for RTs, error rates, and missing data are provided in Table 2.

Statistical analyses

Statistical analyses were conducted using IBM SPSS version 29.0 and R (v4.3.2; R Core Team, 2023). To examine the effects of word type (nouns, verbs), valence (negative, neutral, positive), and their possible interaction across groups (cognitively healthy controls, aMCI, mild AD), we averaged RTs for these six categories (excluding naming errors and missing values). We conducted a semi-parametric repeated measures ANOVA, suitable for non-normality and variance heterogeneity in small, unequal samples, via the RM function from the MANOVA.RM package (Bathke et al., 2018; Friedrich et al., 2018). We relied on the parametric bootstrap ANOVA-like statistics with 1000 resampling-iterations. Significant main effects and interactions were followed up by post-hoc tests. The Kruskal-Wallis test compared RTs and error rates across groups. If this test yielded a significant result, post-hoc tests were conducted using the Dunn's test for pairwise comparisons. The Wilcoxon signed-rank test was employed to perform pairwise comparisons within groups for emotional valence and word type. Multiple post-hoc tests corrections were applied using the Bonferroni-Holm method.

Regression analyses were conducted to explore the relative relationship between RTs and group, CERAD scores, sex, age, education, anxiety, and depression, as well as between error rates and these variables. To verify the assumptions for the regression analysis, we assessed the residuals for normal distribution. The Shapiro-Wilk test indicated that RTs were normally distributed [$W(49) = 0.966$; $p = 0.172$], while naming errors were not [$W(49) = 0.935$; $p = 0.009$]. Consequently, a regression analysis with bootstrapping (1000 resampling-iterations) was performed. To address the issue of multicollinearity, we performed a correlation matrix. Table 3 shows the Spearman correlation coefficients for the independent variables. According to Field (2013, p. 402), correlation values above 0.8 suggest multicollinearity. As shown in Table 3, all independent variables exhibited correlations below this threshold, except for GROUP x CERAD, so CERAD was excluded from regression analysis.

Receiver operating characteristic (ROC) curves were generated to assess the ability of the RAN task in differentiating between cognitively healthy controls, aMCI, and mild AD. Sensitivity, specificity, and optimal hypothetical thresholds for RTs and error rates were calculated for aMCI and mild AD. A clinically significant level of diagnostic accuracy was defined as an AUC value of > 0.7 (Akobeng, 2007).

Table 2. Descriptive statistics for each combination of emotional valence and word type.

Emotional valence × word type	Group	n	Mean RT	MIN-MAX	Mean Err	%Err	Mean Miss	%Miss
Negative objects	CHC	20	1103.78 (146.48)	855.50-1428.97	0.80 (0.83)	6.66 (6.91)	0.55 (0.99)	4.58 (8.25)
	aMCI	15	1344.20 (323.84)	839.33-2170.68	1.40 (1.45)	11.66 (12.08)	0.87 (0.83)	7.25 (6.91)
	AD	15	1489.15 (322.90)	1102.72-2011.56	2.40 (2.02)	20.00 (16.83)	1.80 (1.26)	15.00 (10.50)
Negative actions	CHC	20	1182.41 (162.90)	856.08-1496.40	0.80 (1.19)	11.42 (17.00)	0.15 (0.36)	2.14 (5.14)
	aMCI	15	1344.95 (199.15)	846.67-1638.00	1.27 (1.28)	18.14 (18.28)	0.53 (0.64)	7.57 (9.14)
	AD	15	1616.50 (482.11)	1063.20-2478.18	2.40 (1.80)	34.28 (25.71)	1.20 (1.14)	17.14 (16.28)
Neutral objects	CHC	20	941.31 (115.63)	697.85-1183.32	0.15 (0.36)	1.00 (2.40)	0.35 (0.48)	2.33 (3.20)
	aMCI	15	1120.47 (187.54)	728.80-1408.75	0.87 (0.91)	5.80 (6.06)	0.73 (0.70)	4.86 (4.66)
	AD	15	1332.88 (264.38)	890.84-1748.44	1.13 (1.24)	7.53 (8.26)	2.13 (1.72)	14.20 (11.46)
Neutral actions	CHC	20	992.04 (119.18)	824.49-1263.15	1.05 (1.09)	10.50 (10.90)	0.10 (0.30)	1.00 (3.00)
	aMCI	15	1137.11 (203.27)	740.24-1523.73	1.73 (1.28)	17.30 (12.80)	0.20 (0.41)	2.00 (4.10)
	AD	15	1393.44 (268.62)	1060.30-1957.56	2.13 (1.50)	21.3 (15.00)	0.60 (0.82)	6.00 (8.20)
Positive objects	CHC	20	1004.04 (194.03)	702.48-1615.22	0.50 (0.76)	4.54 (6.90)	0.30 (0.57)	2.72 (5.18)
	aMCI	15	1085.46 (161.26)	763.42-1352.51	1.20 (1.14)	10.90 (10.36)	0.40 (0.50)	3.63 (4.54)
	AD	15	1496.74 (494.56)	903.10-2671.28	1.67 (1.29)	15.18 (11.72)	1.27 (1.43)	11.54 (13.00)
Positive actions	CHC	20	895.63 (79.50)	707.71-1012.9	0.20 (0.52)	2.50 (6.50)	0.05 (0.22)	0.32 (2.75)
	aMCI	15	1259.61 (470.49)	890.73-2785.78	0.27 (0.45)	3.37 (5.62)	0.07 (0.25)	0.87 (4.37)
	AD	15	1433.60 (309.60)	965.12-2154.48	1.47 (1.06)	18.37 (13.25)	0.60 (0.63)	7.50 (7.87)

Note.CHC = cognitively healthy control group; aMCI = group of individuals with amnestic mild cognitive impairment; AD = group with individuals with mild Alzheimer disease; n = number of participants; RT = response time in milliseconds (ms); Err = error rate; % Err = mean error rate in percentage; Miss = missing rate; % Miss = mean missing rate in percentage. In parentheses, the standard deviations are provided.

Table 3. Spearman correlation coefficients for the independent variables.

		age	group	sex	CERAD	education	anxiety	depression
age	r_s	1.000	0.511	-0.060	-0.526	-0.240	0.351	0.303
	p	.	< 0.001***	0.679	< 0.001***	0.093	0.013*	0.034*
group	r_s	0.511	1.000	0.089	-0.916	-0.377	0.345	0.418
	p	< 0.001***	.	0.540	< 0.001***	0.007**	0.015*	0.003**
sex	r_s	-0.060	0.089	1.000	-0.164	0.164	0.127	0.250
	p	0.679	0.540	.	0.255	0.256	0.385	0.083
CERAD	r_s	-0.526	-0.916	-0.164	1.000	0.338	-0.337	-0.373
	p	< 0.001***	< 0.001***	0.255	.	0.017*	0.018*	0.008**
education	r_s	-0.240	-0.377	0.164	0.338	1.000	-0.129	-0.119
	p	0.093	0.007**	0.256	0.017*	.	0.376	0.415
anxiety	r_s	0.351	0.345	0.127	-0.337	-0.129	1.000	0.714
	p	0.013*	0.015*	0.385	0.018*	0.376	.	< 0.001***
depression	r_s	0.303	0.418	0.250	-0.373	-0.119	0.714	1.000
	p	0.034*	0.003**	0.083	0.008**	0.415	< 0.001**	.

*p < 0.05, **p < 0.01, ***p < 0.001

Results

To address the research question of how word class and emotional valence influence speeded naming performance across the groups, we conducted semi-parametric ANOVAs comparing cognitively healthy controls, aMCI, and mild AD groups. For RTs, significant main effects were found for group [$F(1.64, 77.04) = 18.90$, $p < 0.001$], and valence [$F(1.41, Inf) = 24.16$, $p < 0.001$]. However, no significant main effect was found for word type [$F(1, Inf) = 1.86$, $p = 0.172$]. Additionally, there was no significant interaction between group and valence [$F(2.14, Inf) = 0.39$, $p = 0.691$], suggesting that emotional valence affected RTs similarly across all groups.

Regarding naming accuracy, significant main effects were found for group [$F(1.79, 129.25) = 17.74$, $p < 0.001$] and valence [$F(1.75, Inf) = 6.67$, $p = 0.002$], but not for word type [$F(1, Inf) = 0.65$, $p = 0.419$]. There was a significant interaction between word type and valence [$F(1.65, Inf) = 13.42$, $p < 0.001$], which again was consistent across all groups, indicating no three-way interaction. No significant interactions were observed between group and word type [$F(1.67, Inf) = 0.38$, $p = 0.646$], or between group and valence [$F(2.89, Inf) = 0.93$, $p = 0.42$].

Differences in naming performance by emotional valence

The Kruskal-Wallis test revealed significant group differences for negative [$H(2) = 23.18$, $p < 0.001$], positive [$H(2) = 28.31$, $p < 0.001$], and neutral pictures [$H(2) = 28.15$, $p < 0.001$]. Dunn's test for pairwise comparisons showed that cognitively healthy controls responded significantly faster to negative, positive, and neutral pictures than aMCI (all p-values <0.008) and mild AD patients (all p-values <0.001). Additionally, aMCI patients responded faster to positive and neutral pictures than mild AD patients (all p-values <0.040), but not to negative ones ($z = 1.50$, $p = 0.133$).

Regarding naming accuracy, significant group differences were found for negative [$H(2) = 12.69$, $p = 0.001$], positive [$H(2) = 17.3$, $p < 0.001$], and neutral pictures [$H(2) = 12.18$, $p = 0.002$]. Controls made significantly fewer errors than mild AD patients for negative, positive, and neutral pictures (all $p < 0.004$), but differed from aMCI patients only for neutral pictures ($z = 2.49$, $p = 0.025$). Individuals with aMCI made significantly fewer errors than mild AD patients for positive pictures ($z = 2.54$, $p = 0.021$).

To address the hypothesis of [negative delay] and to provide a more nuanced analysis of group differences in naming performance across emotional valence, we conducted pairwise comparisons of valence within each group using the Wilcoxon signed-rank test. As shown in Figure 1, controls responded significantly slower to negative versus positive ($V = 0$, $p < 0.001$) and neutral pictures ($V = 210$, $p < 0.001$), with no significant difference between positive and neutral pictures ($V = 93$, $p = 0.674$). Similarly, aMCI patients showed significantly slower responses to negative versus neutral ($V = 119$, $p < 0.001$) and negative versus positive pictures ($V = 20$, $p = 0.021$), with no significant difference between positive and neutral pictures ($V = 69$, $p = 0.638$). However, mild AD patients responded significantly faster to neutral versus negative ($V = 106$, $p = 0.006$) and positive pictures ($V = 96$, $p = 0.041$). No significant difference in RTs between positive and negative pictures was

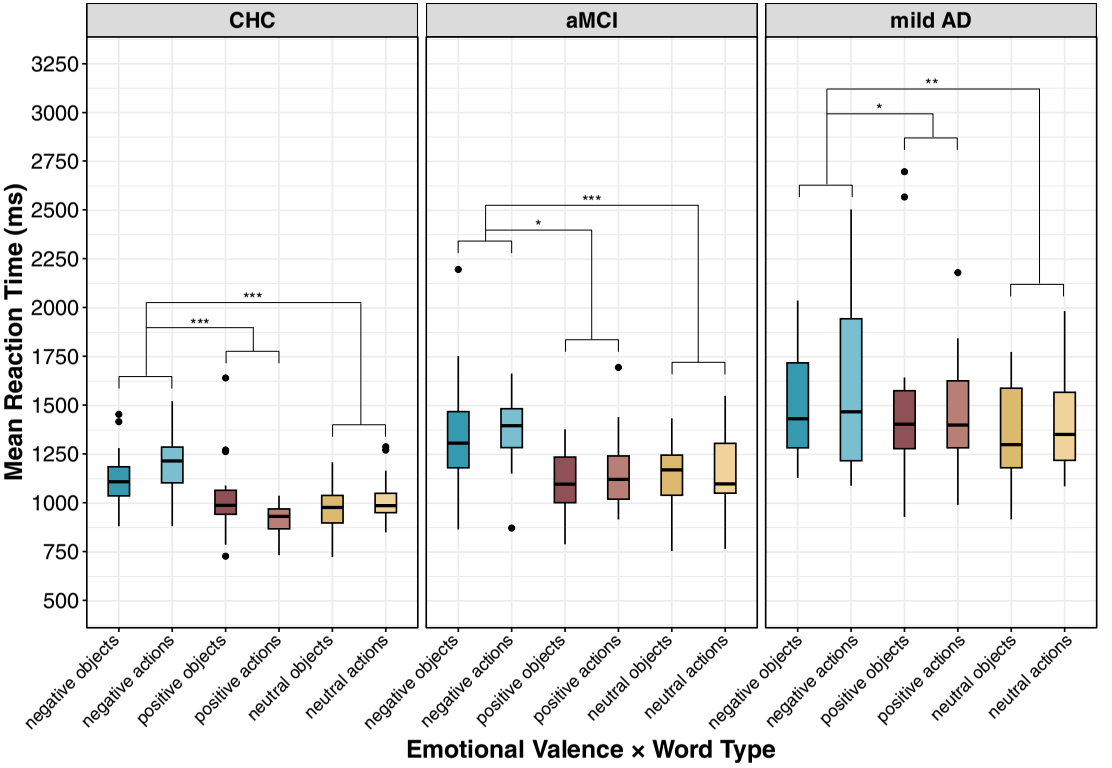

Figure 1. Mean response times (in milliseconds, ms) by emotional valence word type across the groups; p-values for within-group analyses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

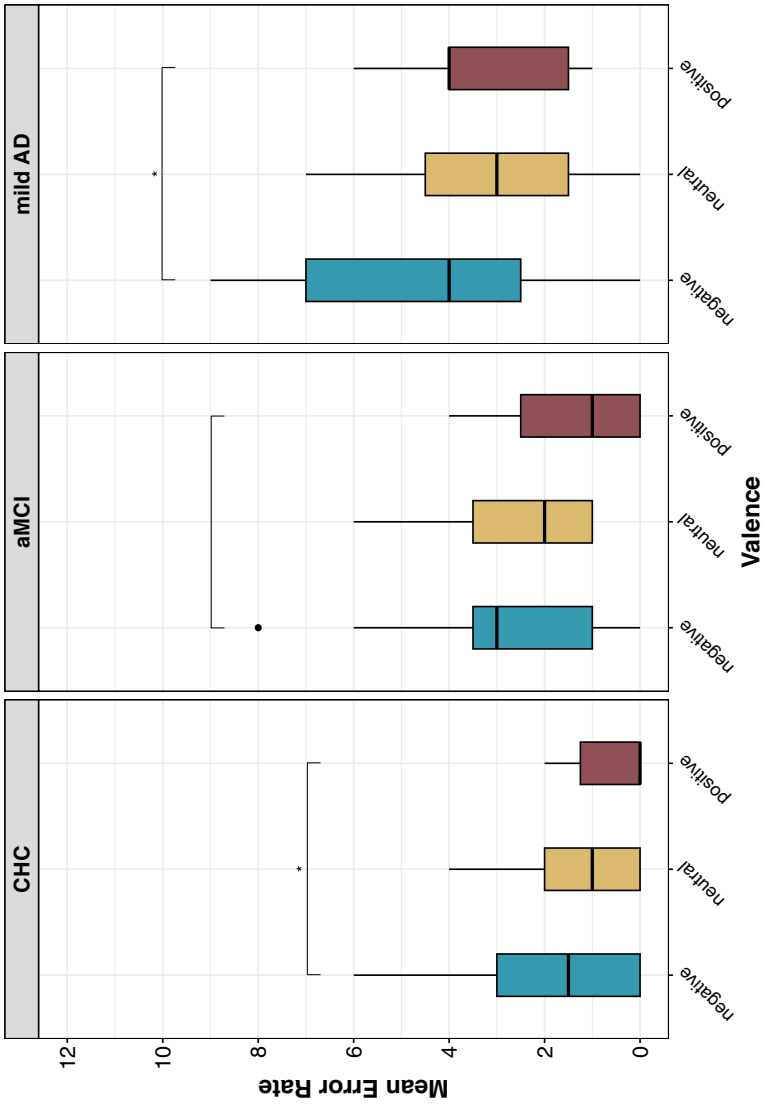

Figure 2. Mean error rates by emotional valence across the groups; p-values for within-group analyses: *p < 0.05, **p < 0.01, *** p * 0.001.

observed (V = 48, $p = 0.524$), indicating that the positive-negative difference was diminished in this group.

Regarding naming accuracy, controls made significantly more errors with negative pictures compared to positive ones (V = 28, $p = 0.038$), while no significant differences were found between positive and neutral (V = 36.5, $p = 0.171$), or negative and neutral picture naming (V = 72, $p = 0.221$) in this group.

As shown in Figure 2, the aMCI group made marginally more errors for negative than positive pictures (V = 14, $p = 0.052$), with no significant differences for negative versus neutral (V = 28, $p = 1$) or positive versus neutral pictures (V = 24, $p = 0.135$).

In mild AD, significantly more errors occurred for negative than positive pictures (V = 21.5, $p = 0.029$). However, no significant differences were found in errors between negative and neutral pictures (V = 77, $p = 0.129$), nor between positive and neutral pictures (V = 41, $p = 0.777$).

In cognitively healthy controls, no significant valence-related differences in missing data were found (all p-values >0.250). In aMCI, significantly more *missings* occurred for negative versus positive (V = 0, $p = 0.012$) and neutral versus positive pictures (V = 0, $p = 0.026$). No significant difference was found between negative and neutral pictures (V = 27, $p = 0.221$). In mild AD, significantly more *missings* were observed for negative versus positive pictures (V = 6.5, $p = 0.019$). No significant differences were found between positive and neutral pictures (V = 12.5, $p = 0.07$), or negative and neutral pictures (V = 33.5, $p = 0.56$).

Post-hoc analysis examining the interaction between emotional valence and word type within each group was conducted using the Wilcoxon signed-rank test. Controls named neutral object pictures marginally faster than neutral action pictures (V = 53, $p = 0.053$). In contrast, positive action pictures were named significantly faster than positive object pictures (V = 177, $p = 0.005$). No significant difference in RTs was found between negative object pictures and negative action pictures (V = 64, $p = 0.132$). In aMCI and mild AD groups, emotional valence did not significantly affect word type (all p-values >0.359).

Regarding naming accuracy, controls and aMCI patients made significantly more errors naming neutral action pictures compared to neutral object pictures (CHC: V = 126, $p < 0.001$; aMCI: V = 20, $p = 0.037$), while no significant differences were found for mild AD patients (V = 18.5, $p = 0.059$). For positive pictures, controls and aMCI patients made significantly more errors with object than action pictures (CHC: V = 286, $p = 0.017$; aMCI: V = 45, p-value = 0.007). No significant differences were observed in the mild AD group (V = 29.5, $p = 0.875$). Naming negative object versus action pictures did not yield significant differences in any of the groups (all p-values >0.900).

Differences in naming performance by word type

Regarding our [noun-verb dichotomy]-hypothesis, there was no significant main effect of word type, nor was there a significant interaction between group and word type in terms of RTs or naming accuracy (all p-values >0.172). This suggests similar naming performance across groups for object and action pictures. However, object pictures showed significantly more *missings* than action pictures in cognitively healthy controls (V = 70, $p = 0.015$), aMCI patients (V = 65, $p = 0.041$), and individuals with mild AD (V = 85, $p = 0.044$).

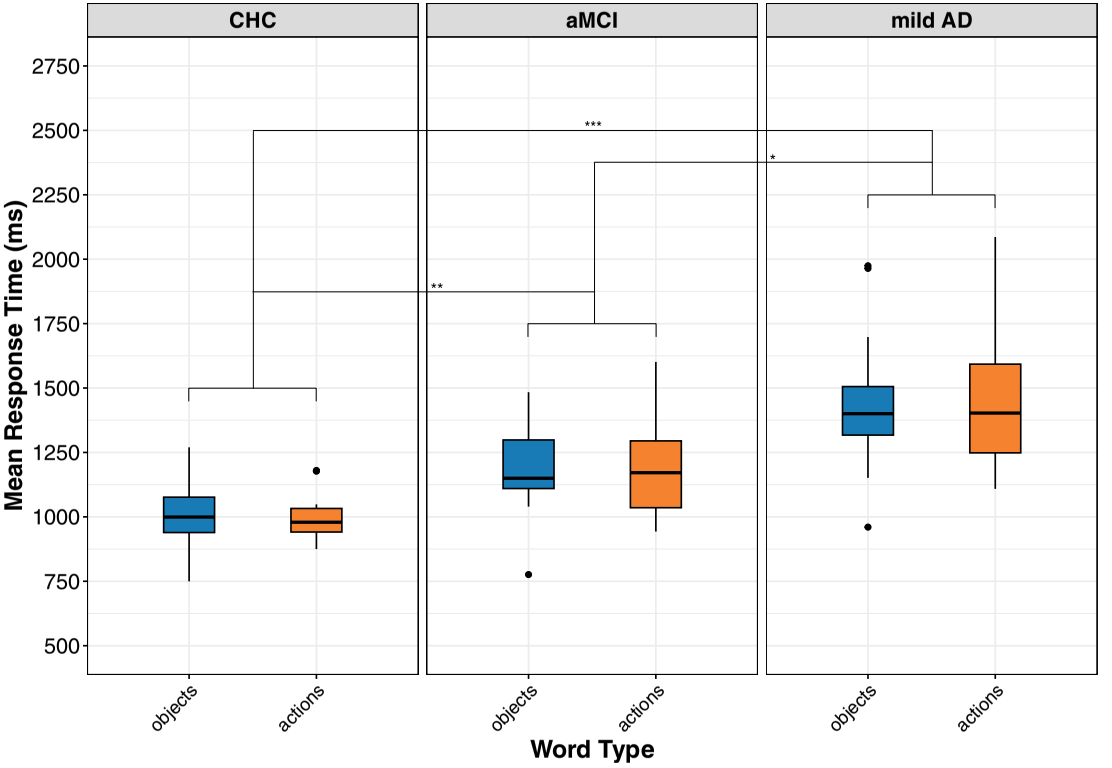

Figure 3. Mean response times (in milliseconds, ms) by word type across the groups; p-values for group comparisons pertain to the overall average RTs: *p < 0.05, **p < 0.01, ***p < 0.001.

Differences in processing speed between the groups

As expected in our hypothesis of [slowed processing speed] and illustrated in Figure 3, the Kruskal-Wallis test revealed significant differences in average RTs between the groups [$H(2) = 29.56$, $p < 0.001$]. Dunn's test for pairwise comparisons indicated that mild AD patients responded significantly slower than individuals with aMCI ($z = 2.20$, $p = 0.027$), who, in turn, responded significantly slower than controls ($z = 3.02$, $p = 0.005$). Mild AD patients were also significantly slower than controls ($z = 5.38$, $p < 0.001$).

Qualitative error analysis

To better understand the errors made by participants, we performed a qualitative error analysis to uncover the underlying cognitive processes and patterns.

Group comparisons were conducted using the independent-samples Kruskal-Wallis test, followed by post-hoc Dunn's test with Bonferroni-Holm adjustment of p-values for significant results.

Significant group differences were observed in overall naming errors [$H(2) = 23.76$, $p < 0.001$]. Cognitively healthy controls made significantly fewer errors than individuals with aMCI ($z = 2.75$, $p = 0.011$) and mild AD ($z = 4.81$, $p < 0.001$). Patients with mild AD showed slightly higher, though not statistically significant ($z = 1.93$, $p = 0.053$), naming errors than those with aMCI.

Specifically, as depicted in Figure 4, significant differences were found in rule-breaking errors [$H(2) = 16.75$, $p < 0.001$] between controls and AD patients ($z = 4.08$, $p < 0.001$), but not between controls and aMCI patients ($z = 2.06$, $p = 0.079$). Additionally, significant differences emerged in semantically unrelated errors [$H(2) = 10.37$, $p = 0.005$], where individuals with aMCI and mild AD (both p-values <0.019) made significantly more errors than controls. There was a significant difference between the groups in semantically related errors [$H(2) = 6.726$, $p = 0.034$], but this difference did not reach significance in pairwise comparisons (all p-values >0.072). No significant differences in any error types were found between the aMCI and mild AD groups (all p-values >0.079).

Significant group differences in missing data were observed [$H(2) = 21.40$, $p < 0.001$]. Controls had significantly fewer *missings* than mild AD patients ($z = 4.62$, $p < 0.001$). Individuals with aMCI exhibited significantly fewer missing data than those with mild AD ($z = 2.67$, $p = 0.015$) but did not differ significantly from controls ($z = 1.77$, $p = 0.077$).

The efficacy of the RAN task in distinguishing cognitively healthy individuals, aMCI, and mild AD

Given that our groups were not well-matched, we conducted multiple regression analyses with age, sex, education, anxiety, and depression as covariates. We also performed separate regression analyses for each group to explore how these variables influence RTs and error rates across the groups.

When considering all participants, multiple regression analyses revealed significant associations between RTs and group ($p < 0.001$), while age, sex, education, anxiety, and

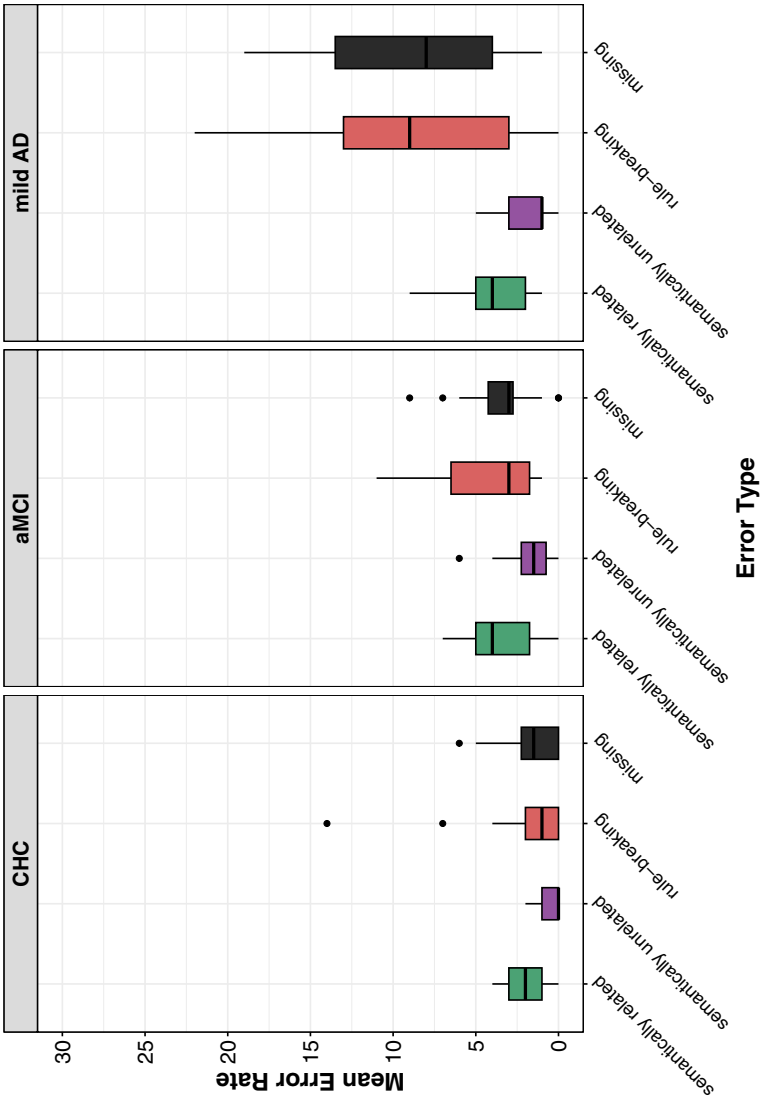

Figure 4. Mean error rates by error types across the groups.

Table 4. Multiple regression results showing the association between RTs/error rates and group, age, sex, education, anxiety, and depression for (a) all participants, (b) cognitively healthy controls (CHC) only, and (c) aMCI and (d) mild AD groups.

	Coefficients	b (SE)	ß	t	p	95% CI	
RTs						Lower Bound	Upper Bound
(a) All participants	group	178.251 (40.388)	0.592	4.413	< 0.001***	96.801	259.701
	age	4.837 (4.886)	0.121	0.990	0.328	-5.016	14.689
	sex	3.769 (52.831)	0.008	0.071	0.943	-102.775	110.313
	education	12.469 (10.896)	0.127	1.144	0.259	-9.504	34.442
	anxiety	10.834 (11.761)	0.141	0.921	0.362	-12.884	34.552
	depression	7.929 (13.074)	0.096	0.606	0.547	-18.437	34.295
(a) CHC	age	7.494 (5.623)	0.361	1.333	0.204	-4.567	19.554
	sex	2.387 (46.894)	0.013	0.051	0.960	-98.190	102.964
	education	-3.067 (10.357)	-0.075	-0.296	0.772	-25.280	19.147
	anxiety	7.952 (13.367)	0.191	0.595	0.561	-20.716	36.621
	depression	-5.612 (15.378)	-0.124	-0.365	0.721	-38.594	27.370
(a) aMCI	age	0.617 (8.192)	0.023	0.075	0.941	-17.636	18.870
	sex	-39.079 (116.455)	-0.105	-0.336	0.744	-298.557	220.398
	education	27.079 (17.355)	0.505	1.560	0.150	-11.591	65.749
	anxiety	9.193 (19.261)	0.158	0.477	0.643	-33.722	52.108
	depression	12.381 (22.485)	0.188	0.551	0.594	-37.718	62.480
(a) mild AD	age	6.579 (20.050)	0.147	0.328	0.751	-39.657	52.815
	sex	76.824 (245.483)	0.148	0.313	0.762	-489.261	642.909
	education	10.190 (64.478)	0.054	0.158	0.878	-138.497	158.876
	anxiety	25.010 (42.629)	0.381	0.587	0.574	-73.293	123.313
	depression	-9.745 (49.982)	-0.132	-0.195	0.850	-125.002	105.513
(a) All participants	group	4.908 (0.942)	0.030		< 0.001***	3.066	6.824
	age	0.000 (0.127)	-0.008		0.998	-0.278	0.217
	sex	-1.385 (1.435)	0.011		0.331	-4.233	1.481
	education	-0.041(0.249)	-0.017		0. 875	-0.615	0.434
	anxiety	0.315 (0.028)	0.028		0.321	-0.274	0.901
	depression	-0.323 (0.352)	-0.029		0.340	-1.074	0.306

(*Continued*)

Table 4. (Continued).

RTs	Coefficients	b (SE)	ß	t	p	95% CI	
						Lower Bound	Upper Bound
(a) CHC	age	0.073 (0.351)	0.039		0.679	-0.330	1.136
	sex	0.012 (1.624)	0.090		0.997	-2.954	2.949
	education	-0.638 (0.516)	-0.060		0.206	-1.883	0.123
	anxiety	-0.382 (0.597)	-0.092		0.437	-2.026	0.425
	depression	-0.325 (0.538)	0.097		0.497	-1.141	0.856
(a) aMCI	age	-0.255 (0.474)	0.039		0.474	-0.848	0.464
	sex	-4.417 (6.834)	0.690		0.359	-14.401	6.411
	education	1.170 (3.191)	-0.071		0.205	-2.754	6.350
	anxiety	0.705 (0.983)	0.116		0.348	-0.485	2.876
	depression	-0.459 (1.971)	-0.157		0.685	-2.958	1.602
(a) mild AD	age	-0.229 (2.337)	-0.591		0.716	-5.101	0.904
	sex	-3.341 (17.088)	-2.950		0.741	-33.845	15.585
	education	-0.171 (2.226)	-0.097		0.861	-4.120	2.967
	anxiety	0.966 (2.116)	0.188		0.416	-1.624	4.173
	depression	-0.733 (3.643)	0.102		0.637	-3.975	2.469

*p < 0.05, **p < 0.01, ***p < 0.001

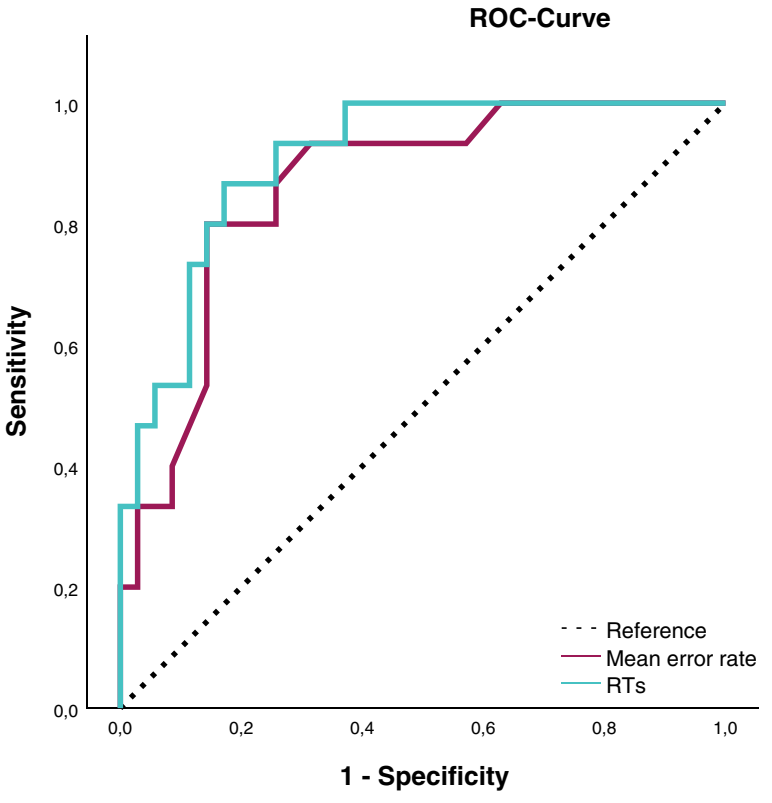

Figure 5. Receiver Operating Characteristic (ROC) curves comparing sensitivity and specificity of mean response times (RTs; in blue) and mean error rates(in purple) for distinguishing cognitively healthy controls from individuals with mild AD.

depression showed no significant associations, as given in Table 4. This model explained 56.4% of RT variance [$R^2 = 0.564$, $F(6,42) = 11.366$; $p < 0.001$].

Similarly, group significantly predicted error rates ($p < 0.001$), while age, sex, education, anxiety, and depression did not. This model accounted for 49.1% of the variance in error rates [$R^2 = 0.491$, $F(6,42) = 6.750$; $p < 0.001$].

Separate analyses by group confirmed no significant effects for the covariates on RTs or error rates (Table 4b-d).

To evaluate whether our naming task can detect early AD-specific changes in lexical-semantic retrieval and distinguish between cognitively healthy controls, individuals with aMCI, and those with mild AD, we conducted ROC curve analyses. Figure 5 depicts ROC curves for classifying participants based on RTs and error rates. RAN performance provided moderate diagnostic accuracy for classifying mild AD (AUC = 0.907; SE = 0.041; $p < 0.001$; 95% CI = 0.826, 0.987). As indicated by Youden Index 1194.20 ms for RTs represents an optimal threshold for the classification of AD with a sensitivity and specificity of 86% and 83%. However, RAN performance did not provide acceptable diagnostic accuracy for classifying aMCI (AUC = 0.571; SE = 0.08; $p = 0.382$; 95% CI = 0.411, 0.732).

Error rates provided moderate diagnostic accuracy for classifying mild AD versus cognitively healthy controls (AUC = 0.861; SE = 0.054; $p < 0.001$; 95% CI = 0.755, 0.967).

As indicated by Youden Index an error rate of 11 out of 79 pictures (14%) represents an optimal threshold for the classification of AD with a sensitivity and specificity of 80% and 85%. Conversely, error rates did not provide acceptable diagnostic accuracy for classifying aMCI versus cognitively healthy participants (AUC = 0.569; SE = 0.082; $p = 0.403$; 95% CI = 0.408, 0.729).

Discussion

This study aimed to evaluate the utility of a RAN task in distinguishing cognitively healthy controls, individuals with aMCI, and those with mild AD. We explored the impact of emotional valence, word class, and processing speed on naming performance. Our findings demonstrate that the RAN task reliably identifies naming impairments (measured by RTs and accuracy) across different stages of cognitive decline associated with AD, independent of factors such as age, sex, education, anxiety, and depression.

The impact of emotional valence on word retrieval processes

Examining valence effects on word processing is complicated by arousal interference, particularly for negative stimuli. Contrary to previous findings suggesting a facilitative effect of high arousal on processing negative words (Hofmann et al., 2009), our results align with studies showing inhibitory effects of high-arousal negative pictures on lexical retrieval (Blackett et al., 2017; Schwen Blackett et al., 2024). Longer RTs and higher error rates for higher-arousal negative stimuli in our cognitively healthy participants suggest higher attention allocation for negative emotions. Both our findings and those of Blackett et al. support the "negative delay" phenomenon in healthy controls, which is therefore not necessarily indicative of pathological changes in semantic memory retrieval. Although the interaction between group and valence was not significant in our study, within-group analysis showed a weakened positive-negative discrepancy in the patient groups, becoming nonsignificant in the AD group. This may be due to greater variance within these groups, reflecting the typical cognitive variability seen in AD patients. Additionally, in our study, negative pictures had higher arousal ratings than positive and neutral pictures, which could also explain the similar performance across these two valences. AD patients may show a weaker reaction to negative stimuli, leading to a less pronounced "negative delay". This suggests impairments in emotional processing networks (e.g., the amygdala and limbic system; Mistridis et al., 2013), especially concerning arousal. Nevertheless, negative pictures remained cognitively demanding, as indicated by higher error rates. This indicates that emotional content of words can influence lexical-semantic retrieval independently of emotional reactivity.

Additionally, heightened levels of anxiety and depression in AD patients (Botto et al., 2022) may further complicate emotional processing. Despite lacking a formal diagnosis of anxiety or depressive disorder, the significantly higher self-reported depression scores in this group suggest increased sensitivity to negative stimuli (Ahorsu & Tsang, 2018; Mogg & Bradley, 1998; Theódórsdóttir & Höller, 2023), potentially explaining the absent positive-negative RT difference in our mild AD group. This underscores the need to control for anxiety and depression in studying emotional processing studies.

Emotions interact with semantic variables like word concreteness (Hinojosa et al., 2020; Vigliocco et al., 2013). For instance, Vigliocco et al. (2013) proposed that emotions exert a more pronounced influence on abstract words than concrete ones. Our results partially support this, as in cognitively healthy controls, action pictures were named significantly faster and more accurately than object pictures in the positive condition, but no significant difference was found for negative pictures. This suggests that emotions may facilitate the retrieval of abstract words, in our case, verbs. The "negative delay" effect in RTs and error rates may interfere with the facilitatory effect of emotion on abstract words, leading to a weakened effect for negative verbs. However, claiming that emotions play a more important role in abstract words than in concrete words is too simplistic based on current research, especially since this interaction was weakened in our aMCI or no longer evident in our AD groups. This indicates that the interplay between emotions and semantic variables such as concreteness also depends on cognitive health.

Interestingly, the reduction in the negative delay effect may vary depending on the cognitive resources available for emotion regulation. Future research could explore how emotional interference in lexical retrieval evolves across different stages of AD.

Is there a noun-verb dichotomy in AD?

Our results align with studies showing no clear selective preservation of verbs in AD (Cappa et al., 1998; Druks et al., 2006; Lukic et al., 2021; Masterson et al., 2007; Williams et al., 2021). Rather, they support the assumption that nouns and verbs are represented in the same unitary distributed fronto-temporal network when neither nouns nor verbs are inflected (Tyler et al., 2004). While naming object and action pictures showed no significant differences, aMCI and mild AD patients tended to have shorter RTs and fewer errors for nouns than verbs. Conversely, controls exhibited a slight, non-significant advantage for action naming. Additionally, the facilitatory effect of positive emotions on action naming in cognitively healthy controls was weakened or absent in the patient groups. This supports the idea that emotional aspects impact word retrieval differently in cognitively impaired individuals. It also aligns with the view that nouns and verbs have differently semantically rich representations (Nickels & Howard, 1995) and pose different demands on the processing system (Bird et al., 2003; Crepaldi et al., 2006; Druks et al., 2006; Faroqi-Shah et al., 2018; Lukic et al., 2021). However, caution is warranted in interpreting these findings due to substantial variance within our groups, and the limited significance of isolated words for discussions on the noun-verb distinction (Baker, 2015).

Processing speed deficits in aMCI and mild AD: insights from RAN data

Our RT data support our hypothesis that processing speed is compromised in aMCI and mild AD patients, irrespective of sex, age, education, anxiety, and depression. Patient groups showed significantly slower RTs compared to cognitively healthy controls, with aMCI patients performing worse than controls but better than AD patients. This supports the continuum model of AD progression (e.g., Aisen et al., 2017; Sperling et al., 2011). Furthermore, it underscores the importance of processing speed as a sensitive measure for early detection of cognitive impairment (Jacobson et al., 2004).

The significance of processing speed in evaluating dementia was also highlighted in other studies (e.g., Jacobson et al., 2004; Warkentin et al., 2008; Wu et al., 2022). Warkentin et al. (2008), for instance, conducted a study involving 49 AD patients, who were asked to quickly name colours and shapes of 40 combinations. Their findings revealed significantly slower naming speeds in AD patients compared to cognitively healthy controls, with pause times reflecting lexical retrieval deficits in AD. Additionally, these naming difficulties were associated with temporo-parietal relative cerebral blood flow pathology in AD. Consistent with the observations of Warkentin et al. (2008), the slower RTs in our aMCI and mild AD patients were partly attributed to hesitations. This suggests that the progression of AD involves not only a generalized decrease in processing speed but also domain-specific changes, resulting in increased delays and heightened susceptibility to errors in semantic memory retrieval. Our data align with this notion, revealing significantly slower RTs and higher error rates in overall picture naming among aMCI and mild AD patients compared to cognitively healthy controls. Furthermore, these deficits worsen with disease progression, as evidenced by our comparison between the control, aMCI, and mild AD groups.

What the error patterns tell us about the underlying impairment

Previous research suggested that AD patients may have worse naming abilities than controls in terms of the number but not in terms of the type of naming errors (Gale et al., 2008; Lin et al., 2013). However, our findings align with Silagi et al. (2015), suggesting that AD patients may show both quantitative and qualitative differences in naming errors compared to controls.

The error patterns observed in our control group may reflect age-related changes in executive functions (Ferguson et al., 2021) and word retrieval abilities (Barresi et al., 2000; Shafto et al., 2007). These word-finding failures are attributed to difficulties in accessing lexical entries from an otherwise intact semantic system (Nicholas et al., 1996). In contrast, the increase in semantically unrelated errors in aMCI and mild AD patients suggests a semantic deficit or loss of semantic knowledge (Joubert et al., 2010; Moreaud et al., 2001). Notably, rule-breaking errors were more frequent in both patient groups, especially in the mild AD, suggesting impairments in executive functions crucial for adherence to task rules (Rainville et al., 2002). The higher number of missing data in AD patients, due to unintended comments or laughter, further supports impaired executive function (i.e., inhibition). These findings align with studies showing early executive dysfunction in AD (Crowell et al., 2002; Junquera et al., 2020; Kim et al., 2016; Perry & Hodges, 1999; Rainville et al., 2002) and its potential as an early detection measure of AD (Yuspeh et al., 2002).

Overall, our results support the view that naming difficulties in aMCI and mild AD stem from a combination of impaired higher-order cognitive processes, impaired lexical retrieval, and a loss of semantic knowledge (Balthazar et al., 2008).

Limitations and future directions

Despite significant differences in RTs and error rates between the aMCI, mild AD, and control groups, further research with larger, well-matched samples is needed. The small sample size warrants cautious interpretation and the high variability within the patient groups complicates interpretation. However, this interindividual variability should be viewed as an inherent aspect of the disease and may provide additional insights (LaPlume et al., 2021). Although not decisive in our study, factors like age, education, and gender influence confrontation naming performance (Randolph et al., 1999; Stasenko et al., 2019), making comparisons to adjusted norms essential to determine cognitive impairment accurately.

A limitation of our study is the lack of standardized visual stimuli and reliance on emotional valence ratings from written words, which may not precisely reflect emotional responses during picture naming. Standardizing stimuli and establishing normative data for confrontation naming tasks are crucial for accurately assessing word retrieval impairments.

Given the varying richness of semantic representations and the differing impact of emotions on processing objects and actions, an approach focused on word-category-specific naming performance could provide a more nuanced understanding of lexical-semantic abilities. Since emotions influence word retrieval and semantic representations, their inclusion in assessments is essential.

While our discrete RAN paradigm offers insights into word retrieval processes, it poses technical challenges, such as the need for manual post-processing due to late or early voice key detections, which is time-consuming and requires linguistic expertise. Therefore, further efforts are needed for clinical use.

Conclusion

Our study underscores the utility of the RAN task in distinguishing cognitively healthy controls, aMCI, and mild AD based on emotional valence, word class, and processing speed. Emotional valence influenced word retrieval, with negative stimuli slowing lexical access and increasing naming errors in cognitively healthy controls. In contrast, patient groups showed a weakened "negative delay", likely due to cognitive variability and impaired emotional reactivity. Nevertheless, negative stimuli remained cognitively demanding for aMCI and mild AD patients, as indicated by lower accuracy, suggesting that emotional valence influences retrieval processes independently of emotional reactivity. Our findings point to altered emotional processing in cognitive decline and emphasize the importance of incorporating emotional valence, word class, and processing speed into naming tests to enhance assessments of lexical-semantic abilities and to aid in monitoring cognitive disorders like AD.

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References

Ahorsu, D., & Tsang, H. (2018). The effects of emotional expressions on attention-inhibition processes of depressed patients: An ERP systematic review. *Neuropsychiatry*, *8*(6), 1913–1922. https://doi.org/10.4172/Neuropsychiatry.1000534

Aisen, P. S., Cummings, J., Jack, C. R., Jr., Morris, J. C., Sperling, R., Frölich, L., Jones, R. W., Dowsett, S. A., Matthews, B. R., Raskin, J., Scheltens, P., & Dubois, B. (2017). On the path to 2025: Understanding the Alzheimer's disease continuum. *Alzheimer's Research and Therapy*, *9*, 1–10. https://doi.org/10.1186/s13195-017-0283-5

Akobeng, A. K. (2007). Understanding diagnostic tests 1: Sensitivity, specificity and predictive values. *Acta Paediatrica*, *96*(3), 338–341. https://doi.org/10.1111/j.1651-2227.2006.00180.x

Alzheimer's Association, (2023). Alzheimer's disease facts and figures. *Alzheimer's & Dementia*, *19*(4), 1598–1695. https://doi.org/10.1002/alz.13016

Baker, M. (2015). Nouns, verbs, and verbal nouns: Their structure and their structural cases. In J. Blaszczak, D. Klimek-Jankowska, & K. Migdalski (Eds.), *How categorical are categories?: New approaches to the old questions of noun, verb, and adjective* (pp. 13–46). De Gruyter Mouton. https://doi.org/10.1515/9781614514510-003

Balthazar, M. L., Cendes, F., & Damasceno, B. P. (2008). Semantic error patterns on the Boston naming test in normal aging, amnestic mild cognitive impairment, and mild Alzheimer's disease: Is there semantic disruption? *Neuropsychology*, *22*(6), 703–709. https://doi.org/10.1037/a0012919

Barresi, B., Nicholas, M., Connor, L., Obler, L., & Albert, M. (2000). Semantic degradation and lexical access in age-related naming failures. *Aging, Neuropsychology & Cognition*, *7*(3), 169–178. https://doi.org/10.1076/1382-5585(200009)7:3;1-Q;FT169

Bathke, A. C., Friedrich, S., Pauly, M., Konietschke, F., Staffen, W., Strobl, N., & Höller, Y. (2018). Testing mean differences among groups: Multivariate and repeated measures analysis with minimal assumptions. *Multivariate Behavioral Research*, *53*(3), 348–359. https://doi.org/10.1080/00273171.2018.1446320

Bird, H., Howard, D., & Franklin, S. (2003). Verbs and nouns: The importance of being imageable. *Journal of Neurolinguistics*, *16*(2), 113–149. https://doi.org/10.1016/S0911-6044(02)00016-7

Blackett, D. S., Harnish, S. M., Lundine, J. P., Zezinka, A., & Healy, E. W. (2017). The effect of stimulus valence on lexical retrieval in younger and older adults. *Journal of Speech, Language, and Hearing Research*, *60*(7), 2081–2089. https://doi.org/10.1044/2017_jslhr-l-16-0268

Boersma, P., & Weenink, D. (1992–2022). Praat: Doing phonetics by computer (Version 6.2.06) [Computer software]. Retrieved February 17, 2022, https://www.praat.org/.

Botto, R., Callai, N., Cermelli, A., Causarano, L., & Rainero, I. (2022). Anxiety and depression in Alzheimer's disease: A systematic review of pathogenetic mechanisms and relation to cognitive decline. *Neurological Sciences*, *43*(7), 4107–4124. https://doi.org/10.1007/s10072-022-06068-x

Braak, H., & Braak, E. (1991). Neuropathological stageing of Alzheimer-related changes. *Acta Neuropathologica*, *82*(4), 239–259. https://doi.org/10.1007/bf00308809

Cappa, S. F., Binetti, G., Pezzini, A., Padovani, A., Rozzini, L., & Trabucchi, M. (1998). Object and action naming in Alzheimer's disease and frontotemporal dementia. *Neurology*, *50*(2), 351–355. https://doi.org/10.1212/wnl.50.2.351

Chandler, M. J., Lacritz, L. H., Hynan, L. S., Barnard, H. D., Allen, G., Deschner, M., Weiner, M. F., & Cullum, C. M. (2005). A total score for the CERAD neuropsychological battery. *Neurology*, *65*(1), 102–106. https://doi.org/10.1212/01.wnl.0000167607.63000.38

Chenery, H. J., Murdoch, B. E., & Ingram, J. C. L. (1996). An investigation of confrontation naming performance in Alzheimer's dementia as a function of disease severity. *Aphasiology*, *10*(5), 423–441. https://doi.org/10.1080/02687039608248423

Crepaldi, D., Aggujaro, S., Arduino, L. S., Zonca, G., Ghirardi, G., Inzaghi, M. G., Colombo, M., Chierchia, G., & Luzzatti, C. (2006). Noun-verb dissociation in aphasia: The role of imageability and functional locus of the lesion. *Neuropsychologia*, *44*(1), 73–89. https://doi.org/10.1016/j.neuropsychologia.2005.04.006

Crowell, T. A., Luis, C. A., Vanderploeg, R. D., Schinka, J. A., & Mullan, M. (2002). Memory patterns and executive functioning in mild cognitive impairment and Alzheimer's disease. *Aging, Neuropsychology & Cognition*, *9*(4), 288–297. https://doi.org/10.1076/anec.9.4.288.8772

da Silva, R. C. R., de Carvalho, R. L. S., & Dourado, M. C. N. (2021). Deficits in emotion processing in Alzheimer's disease: A systematic review. *Dementia and Neuropsychologia*, *15*(3), 314–330. https://doi.org/10.1590/1980-57642021dn15-030003

de Jong, P. F. (2011). What discrete and serial rapid automatized naming can reveal about reading. *Scientific Studies of Reading*, *15*(4), 314–337. https://doi.org/10.1080/10888438.2010.485624

DiBenedetti, D. B., Slota, C., Wronski, S. L., Vradenburg, G., Comer, M., Callahan, L. F., Winfield, J., Rubino, I., Krasa, H. B., Hartry, A., Wieberg, D., Kremer, I. N., Lappin, D., Martin, A. D., Frangiosa, T., Biggar, V., & Hauber, B. (2020). Assessing what matters most to patients with or at risk for Alzheimer's and care partners: A qualitative study evaluating symptoms, impacts, and outcomes. *Alzheimer's Research and Therapy*, *12*(1), 90. https://doi.org/10.1186/s13195-020-00659-6

Domahs, U., Wiese, R., Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2008). The processing of German word stress: Evidence for the prosodic hierarchy. *Phonology*, *25*(1), 1–36. https://doi.org/10.1017/S0952675708001383

Druks, J., Masterson, J., Kopelman, M., Clare, L., Rose, A., & Rai, G. (2006). Is action naming better preserved (than object naming) in Alzheimer's disease and why should we ask? *Brain and Language*, *98*(3), 332–340. https://doi.org/10.1016/j.bandl.2006.06.003

Faroqi-Shah, Y., Sebastian, R., & Woude, A. V. (2018). Neural representation of word categories is distinct in the temporal lobe: An activation likelihood analysis. *Human Brain Mapping*, *39*(12), 4925–4938. https://doi.org/10.1002/hbm.24334

Ferguson, H. J., Brunsdon, V. E. A., & Bradford, E. E. F. (2021). The developmental trajectories of executive function from adolescence to old age. *Scientific Reports*, *11*(1), 1382. https://doi.org/10.1038/s41598-020-80866-1

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.). SAGE Publications.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Frey, V. N., Langthaler, P. B., Raphaelis, E., Ring-Dimitriou, S., Kedenko, L., Aigner, E., Martinz, J., Gostner, I., Bathke, A. C., Sungler, P., Studnicka, M., Haschke-Becher, E., Trinka, E., Iglseder, B., & Paulweber, B. (2023). Paracelsus 10, 000: An observational cohort study about the health status of the population of Salzburg, Austria. Rationale, objectives and study design. *Paracelsus Proceedings of Experimental Medicine*, *2*, 1–17. https://doi.org/10.33594/000000600

Friedrich, S., Konietschke, F., & Pauly, M. (2018). Analysis of multivariate data and repeated measures designs with the R package MANOVA.RM. *The R Journal*, *11*(2), 11. https://doi.org/10.32614/RJ-2019-051

Gale, T., Irvine, K., Laws, K., & Ferrissey, S. (2008). The naming profile in Alzheimer patients parallels that of elderly controls. *Journal of Clinical and Experimental Neuropsychology*, *31*(5), 565–574. https://doi.org/10.1080/13803390802360542

Harry, A., & Crowe, S. F. (2014). Is the Boston naming test still fit for purpose? *The Clinical Neuropsychologist*, *28*(3), 486–504. https://doi.org/10.1080/13854046.2014.892155

Helmstaedter, C., Lendt, M., & Lux, S. (2001). *VLMT: Verbaler Lern- und Merkfähigkeitstest* [Verbal Learning and Memory Test]. Beltz Test.

Hermann-Lingen, C., Buss, U., & Snaith, R. P. (2018). *Hospital anxiety and depression scale - German version* (4th ed.). Hogrefe.

Hinojosa, J. A., Moreno, E. M., & Ferré, P. (2020). Affective neurolinguistics: Towards a framework for reconciling language and emotion. *Language, Cognition and Neuroscience*, *35*(7), 813–839. https://doi.org/10.1080/23273798.2019.1620957

Hodges, J. R., & Patterson, K. (1995). Is semantic memory consistently impaired early in the course of Alzheimer's disease? Neuroanatomical and diagnostic implications. *Neuropsychologia*, *33*(4), 441–459. https://doi.org/10.1016/0028-3932(94)00127-B

Hodges, J. R., Salmon, D. P., & Butters, N. (1992). Semantic memory impairment in Alzheimer's disease: Failure of access or degraded knowledge? *Neuropsychologia*, *30*(4), 301–314. https://doi.org/10.1016/0028-3932(92)90104-t

Hofmann, M. J., Kuchinke, L., Tamm, S., Võ, M. L., & Jacobs, A. M. (2009). Affective processing within 1/10th of a second: High arousal is necessary for early facilitative processing of negative but not positive words. *Cognitive, Affective, & Behavioral Neuroscience*, *9*(4), 389–397. https://doi.org/10.3758/9.4.389

Howard, D., & Smith, K. (2002). The effects of lexical stress in aphasic word production. *Aphasiology*, *16*(1–2), 198–237. https://doi.org/10.1080/02687040143000546

Huff, F. J., Corkin, S., & Growdon, J. H. (1986). Semantic impairment and anomia in Alzheimer's disease. *Brain and Language*, *28*(2), 235–249. https://doi.org/10.1016/0093-934x(86)90103-3

Jacobson, J. M., Nielsen, N. P., Minthon, L., Warkentin, S., & Wiig, E. H. (2004). Multiple rapid automatic naming measures of cognition: Normal performance and effects of aging. *Perceptual and Motor Skills*, *98*(3), 739–753. https://doi.org/10.2466/pms.98.3.739-753

Joubert, S., Brambati, S. M., Ansado, J., Barbeau, E. J., Felician, O., Didic, M., Lacombe, J., Goldstein, R., Chayer, C., & Kergoat, M. J. (2010). The cognitive and neural expression of semantic memory impairment in mild cognitive impairment and early Alzheimer's disease. *Neuropsychologia*, *48*(4), 978–988. https://doi.org/10.1016/j.neuropsychologia.2009.11.019

Joubert, S., Gardy, L., Didic, M., Rouleau, I., & Barbeau, E. J. (2021). A meta-analysis of semantic memory in mild cognitive impairment. *Neuropsychology Review*, *31*(2), 221–232. https://doi.org/10.1007/s11065-020-09453-5

Junquera, A., García-Zamora, E., Olazarán, J., Parra, M. A., & Fernández-Guinea, S. (2020). Role of executive functions in the conversion from mild cognitive impairment to dementia. *Journal of Alzheimer's Disease*, *77*(2), 641–653. https://doi.org/10.3233/jad-200586

Kaplan, E., Goodglass, H., & Weintraub, S. (2001). *Boston naming test* (2nd ed.). Lippincott Williams & Wilkins.

Katsumata, Y., Mathews, M., Abner, E. L., Jicha, G. A., Caban-Holt, A., Smith, C. D., Nelson, P. T., Kryscio, R. J., Schmitt, F. A., & Fardo, D. W. (2015). Assessing the discriminant ability, reliability, and comparability of multiple short forms of the Boston naming test in an Alzheimer's disease center cohort. *Dementia and Geriatric Cognitive Disorders*, *39*(3–4), 215–227. https://doi.org/10.1159/000370108

Kauschke, C., Bahn, D., Vesker, M., & Schwarzer, G. (2019). The role of emotional valence for the processing of facial and verbal stimuli - positivity or negativity bias? *Frontiers in Psychology*, *10*, 1654. https://doi.org/10.3389/fpsyg.2019.01654

Kavé, G., & Goral, M. (2018). Word retrieval in connected speech in Alzheimer's disease: A review with meta-analyses. *Aphasiology*, *32*(1), 4–26. https://doi.org/10.1080/02687038.2017.1338663

Kim, S., Kang, Y., Yu, K. H., & Lee, B. C. (2016). Disproportionate decline of executive functions in early mild cognitive impairment, late mild cognitive impairment, and mild Alzheimer's disease. *Dementia and Neurocognitive Disorders*, *15*(4), 159–164. https://doi.org/10.12779/dnd.2016.15.4.159

Kissler, J., & Herbert, C. (2013). Emotion, Etmnooi, or Emitoon? - faster lexical access to emotional than to neutral words during reading. *Biological Psychology*, *92*(3), 464–479. https://doi.org/10.1016/j.biopsycho.2012.09.004

Köper, M., & Walde, S. (2016). Automatically generated affective norms of abstractness, arousal, imageability and valence for 350 000 German lemmas. *Proceedings of the Tenth International Conference on Language Resources and Evaluation (LREC'16)* (pp. 2595–2598). Portorož, Slovenia: European Language Resources Association (ELRA).

LaPlume, A. A., Paterson, T. S. E., Gardner, S., Stokes, K. A., Freedman, M., Levine, B., Troyer, A. K., & Anderson, N. D. (2021). Interindividual and intraindividual variability in amnestic mild cognitive impairment (aMCI) measured with an online cognitive assessment. *Journal of Clinical and Experimental Neuropsychology*, *43*(8), 796–812. https://doi.org/10.1080/13803395.2021.1982867

Li, X., Feng, X., Sun, X., Hou, N., Han, F., & Liu, Y. (2022). Global, regional, and national burden of Alzheimer's disease and other dementias, 1990-2019. *Frontiers in Aging Neuroscience*, *14*, 937486. https://doi.org/10.3389/fnagi.2022.937486

Lima, S., Sevilha, S., & Pereira, M. G. (2020). Quality of life in early-stage Alzheimer's disease: The moderator role of family variables and coping strategies from the patients' perspective. *Psychogeriatrics*, *20*(5), 557–567. https://doi.org/10.1111/psyg.12544

Lin, C.-Y., Chen, T.-B., Lin, K.-N., Yeh, Y.-C., Chen, W.-T., Wang, K.-S., & Wang, P. N. (2013). Confrontation naming errors in Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders*, *37*, 86–94. https://doi.org/10.1159/000354359 1–2

Lukic, S., Borghesani, V., Weis, E., Welch, A., Bogley, R., Neuhaus, J., Deleon, J., Miller, Z. A., Kramer, J. H., Miller, B. L., Dronkers, N. F., & Gorno-Tempini, M. L. (2021). Dissociating nouns and verbs in temporal and perisylvian networks: Evidence from neurodegenerative diseases. *Cortex, A Journal Devoted to the Study of the Nervous System and Behavior*, *142*, 47–61. https://doi.org/10.1016/j.cortex.2021.05.006

Mårdh, S., Nägga, K., & Samuelsson, S. (2013). A longitudinal study of semantic memory impairment in patients with Alzheimer's disease. *Cortex, A Journal Devoted to the Study of the Nervous System and Behavior*, *49*(2), 528–533. https://doi.org/10.1016/j.cortex.2012.02.004

Martínez-Nicolás, I., Carro, J., Llorente, T. E., & García Meilán, J. J. (2019). The deterioration of semantic networks in Alzheimer's disease. In T. Wisniewski (Ed.), *Alzheimer's disease* (pp. 179–191). Codon Publications. https://doi.org/10.15586/alzheimersdisease.2019.ch11

Masterson, J., Druks, J., Kopelman, M., Clare, L., Garley, C., & Hayes, M. (2007). Selective naming (and comprehension) deficits in Alzheimer's disease? *Cortex, A Journal Devoted to the Study of the Nervous System and Behavior*, *43*(7), 921–934. https://doi.org/10.1016/S0010-9452(08)70691-9

Mätzig, S., Druks, J., Masterson, J., & Vigliocco, G. (2009). Noun and verb differences in picture naming: Past studies and new evidence. *Cortex, A Journal Devoted to the Study of the Nervous System and Behavior*, *45*(6), 738–758. https://doi.org/10.1016/j.cortex.2008.10.003

Mazur-Mosiewicz, A., & Davis, A. S. (2011). Rapid automized naming. In S. Goldstein & J. A. Naglieri (Eds.), *Encyclopedia of Child behavior and development* (pp. 1212–1213). Springer US. https://doi.org/10.1007/978-0-387-79061-9_2335

McKhann, G. M., Knopman, D. S., Chertkow, H., Hyman, B. T., Jack, C. R., Jr., Kawas, C. H., Klunk, W. E., Koroshetz, W. J., Manly, J. J., Mayeux, R., Mohs, R. C., Morris, J. C., Rossor, M. N., Scheltens, P., Carrillo, M. C., Thies, B., Weintraub, S., & Phelps, C. H. (2011). The diagnosis of dementia due to Alzheimer's disease: Recommendations from the national institute on aging-Alzheimer's association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's & Dementia*, *7*(3), 263–269. https://doi.org/10.1016/j.jalz.2011.03.005

Mistridis, P., Taylor, K. I., Kissler, J. M., Monsch, A. U., Kressig, R. W., & Kivisaari, S. L. (2013). Distinct neural systems underlying reduced emotional enhancement for positive and negative stimuli in early Alzheimer's disease. *Frontiers in Human Neuroscience*, *7*, 939. https://doi.org/10.3389/fnhum.2013.00939

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy*, *36*(9), 809–848. https://doi.org/10.1016/S0005-7967(98)00063-1

Moreaud, O., David, D., Charnallet, A., & Pellat, J. (2001). Are semantic errors actually semantic?: Evidence from Alzheimer's disease. *Brain and Language*, *77*(2), 176–186. https://doi.org/10.1006/brln.2000.2427

Morris, J. C., Heyman, A., Mohs, R. C., Hughes, J. P., van Belle, G., Fillenbaum, G., Mellits, E. D., & Clark, C. (1989). The consortium to establish a registry for Alzheimer's disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. *Neurology*, *39*(9), 1159–1165. https://doi.org/10.1212/wnl.39.9.1159

Moseley, R., Carota, F., Hauk, O., Mohr, B., & Pulvermüller, F. (2011). A role for the motor system in binding abstract emotional meaning. *Cerebral Cortex*, *22*(7), 1634–1647. https://doi.org/10.1093/cercor/bhr238

Nicholas, M., Obler, L. K., Au, R., & Albert, M. L. (1996). On the nature of naming errors in aging and dementia: A study of semantic relatedness. *Brain and Language*, *54*(2), 184–195. https://doi.org/10.1006/brln.1996.0070

Nickels, L., & Howard, D. (1995). Aphasic naming: What matters? *Neuropsychologia*, *33*(10), 1281–1303. https://doi.org/10.1016/0028-3932(95)00102-9

Noroozian, M., Masumi, J., Khatoonabadi, A., Salehi, M., & Kargar, M. (2018). Picture-naming performance in Persian-speaking patients with mild cognitive impairment and Alzheimer's disease. *Archives of Neuroscience*, *5*(4), 1–5. https://doi.org/10.5812/ans.68036

Palazova, M., Mantwill, K., Sommer, W., & Schacht, A. (2011). Are effects of emotion in single words non-lexical? Evidence from event-related brain potentials. *Neuropsychologia*, *49*(9), 2766–2775. https://doi.org/10.1016/j.neuropsychologia.2011.06.005

Palmer, A. D., Carder, P. C., White, D. L., Saunders, G., Woo, H., Graville, D. J., & Newsom, J. T. (2019). The impact of communication impairments on the social relationships of older adults: Pathways to psychological well-being. *Journal of Speech, Language, and Hearing Research*, *62*(1), 1–21. https://doi.org/10.1044/2018_jslhr-s-17-0495

Perry, R. J., & Hodges, J. R. (1999). Attention and executive deficits in Alzheimer's disease. A critical review. *Brain*, *122*(3), 383–404. https://doi.org/10.1093/brain/122.3.383

Petersen, R. C., Caracciolo, B., Brayne, C., Gauthier, S., Jelic, V., & Fratiglioni, L. (2014). Mild cognitive impairment: A concept in evolution. *Journal of Internal Medicine*, *275*(3), 214–228. https://doi.org/10.1111/joim.12190

Poulin, S. P., Dautoff, R., Morris, J. C., Barrett, L. F., & Dickerson, B. C. (2011). Amygdala atrophy is prominent in early Alzheimer's disease and relates to symptom severity. *Psychiatry Research: Neuroimaging*, *194*(1), 7–13. https://doi.org/10.1016/j.pscychresns.2011.06.014

Rainer, L. J., Kronbichler, M., Kuchukhidze, G., Trinka, E., Langthaler, P. B., Kronbichler, L., Said-Yuerekli, S., Kirschner, M., Zimmermann, G., Höfler, J., Schmid, E., & Braun, M. (2022). Emotional word processing in patients with juvenile myoclonic epilepsy. *Frontiers in Neurology*, *13*, 875950. https://doi.org/10.3389/fneur.2022.875950

Rainville, C., Amieva, H., Lafont, S., Dartigues, J.-F., Orgogozo, J.-M., & Fabrigoule, C. (2002). Executive function deficits in patients with dementia of the Alzheimer's type: A study with a tower of London task. *Archives of Clinical Neuropsychology*, *17*(6), 513–530. https://doi.org/10.1016/S0887-6177(01)00132-9

Randolph, C., Lansing, A. E., Ivnik, R. J., Cullum, C. M., & Hermann, B. P. (1999). Determinants of confrontation naming performance. *Archives of Clinical Neuropsychology*, *14*(6), 489–496. https://doi.org/10.1093/arclin/14.6.489

R Core Team. (2023). *R: A language and environment for statistical computing* [software]. R foundation for statistical computing. https://www.R-project.org/

Salehi, M., Reisi, M., & Ghasisin, L. (2017). Lexical retrieval or semantic knowledge which one causes naming errors in patients with mild and moderate Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders Extra*, *7*(3), 419–429. https://doi.org/10.1159/000484137

Schwen Blackett, D., Borod, J. C., Speer, S. R., Pan, X., & Harnish, S. M. (2024). The effects of emotional stimuli on word retrieval in people with aphasia. *Neuropsychologia*, *192*, 108734. https://doi.org/10.1016/j.neuropsychologia.2023.108734

Shafto, M. A., Burke, D. M., Stamatakis, E. A., Tam, P. P., & Tyler, L. K. (2007). On the tip-of-the-tongue: Neural correlates of increased word-finding failures in normal aging. *Journal of Cognitive Neuroscience*, *19*(12), 2060–2070. https://doi.org/10.1162/jocn.2007.19.12.2060

Silagi, M. L., Bertolucci, P. H., & Ortiz, K. Z. (2015). Naming ability in patients with mild to moderate Alzheimer's disease: What changes occur with the evolution of the disease? *Clinics*, *70*(6), 423–428. https://doi.org/10.6061/clinics/2015(06)07

Sperling, R. A., Aisen, P. S., Beckett, L. A., Bennett, D. A., Craft, S., Fagan, A. M., Iwatsubo, T., Jack, C. R., Jr., Kaye, J., Montine, T. J., Park, D. C., Reiman, E. M., Rowe, C. C., Siemers, E., Stern, Y., Yaffe, K., Carrillo, M. C., Thies, B. & Phelps, C. H. (2011). Toward defining the preclinical stages of Alzheimer's disease: Recommendations from the national institute on aging-Alzheimer's association work-groups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's & Dementia*, *7*(3), 280–292. https://doi.org/10.1016/j.jalz.2011.03.003

Stasenko, A., Jacobs, D. M., Salmon, D. P., & Gollan, T. H. (2019). The multilingual naming test (MINT) as a measure of picture naming ability in Alzheimer's disease. *Journal of the International Neuropsychological Society*, *25*(8), 821–833. https://doi.org/10.1017/s1355617719000560

Steinmetz, J. D., Seeher, K. M., Schiess, N., Nichols, E., Cao, B., Servili, C., Cavallera, V., Cousin, E., Hagins, H., Moberg, M. E., Mehlman, M. L., Abate, Y. H., Abbas, J., Abbasi, M. A., Abbasian, M., Abbastabar, H., Abdelmasseh, M., Abdollahi, M. & Vos, T. (2024) Global, regional, and national burden of disorders affecting the nervous system, 1990-2021: A systematic analysis for the global burden of disease study 2021. *Lancet Neurology*, *23*(4), 344–381. https://doi.org/10.1016/S1474-4422(24)00038-3

Theódórsdóttir, D., & Höller, Y. (2023). Emotional bias among individuals at risk for seasonal affective disorder - an EEG study during remission in summer. *Brain Sciences*, *14*(1), 2. https://doi.org/10.3390/brainsci14010002

Tyler, L. K., Bright, P., Fletcher, P., & Stamatakis, E. A. (2004). Neural processing of nouns and verbs: The role of inflectional morphology. *Neuropsychologia*, *42*(4), 512–523. https://doi.org/10.1016/j.neuropsychologia.2003.10.001

Venneri, A., Mitolo, M., Beltrachini, L., Varma, S., Della Pietà, C., Jahn-Carta, C., Frangi, A. F., & De Marco, M. (2019). Beyond episodic memory: Semantic processing as independent predictor of hippocampal/perirhinal volume in aging and mild cognitive impairment due to Alzheimer's disease. *Neuropsychology*, *33*(4), 523–533. https://doi.org/10.1037/neu0000534

Verma, M., & Howard, R. J. (2012). Semantic memory and language dysfunction in early Alzheimer's disease: A review. *International Journal of Geriatric Psychiatry*, *27*(12), 1209–1217. https://doi.org/10.1002/gps.3766

Vigliocco, G., Kousta, S.-T., Della Rosa, P. A., Vinson, D. P., Tettamanti, M., Devlin, J. T., & Cappa, S. F. (2013). The neural representation of abstract words: The role of emotion. *Cerebral Cortex*, *24*(7), 1767–1777. https://doi.org/10.1093/cercor/bht025

Warkentin, S., Erikson, C., & Janciauskiene, S. (2008). rCBF pathology in Alzheimer's disease is associated with slow processing speed. *Neuropsychologia*, *46*(5), 1193–1200. https://doi.org/10.1016/j.neuropsychologia.2007.08.029

Williams, E., McAuliffe, M., & Theys, C. (2021). Language changes in Alzheimer's disease: A systematic review of verb processing. *Brain and Language*, *223*, 105041. https://doi.org/10.1016/j.bandl.2021.105041

Winblad, B., Palmer, K., Kivipelto, M., Jelic, V., Fratiglioni, L., Wahlund, L. O., Nordberg, A., Bäckman, L., Albert, M., Almkvist, O., Arai, H., Basun, H., Blennow, K., de Leon, M., DeCarli, C., Erkinjuntti, T., Giacobini, E., Graff, C. & Visser, P. (2004). Mild cognitive impairment - beyond controversies, towards a consensus: Report of the International working group on mild cognitive impairment. *Journal of Internal Medicine*, *256*(3), 240–246. https://doi.org/10.1111/j.1365-2796.2004.01380.x

Wu, S. Z., Nolan-Kenney, R., Moehringer, N. J., Hasanaj, L. F., Joseph, B. M., Clayton, A. M., Rucker, J. C., Galetta, S. L., Wisniewski, T. M., Masurkar, A. V., & Balcer, L. J. (2022). Exploration of rapid automatized naming and standard visual tests in prodromal alzheimer disease detection. *Journal of neuro-Ophthalmology*, *42*(1), 79–87. https://doi.org/10.1097/wno.0000000000001228

Yuspeh, R. L., Vanderploeg, R. D., Crowell, T. A., & Mullan, M. (2002). Differences in executive functioning between Alzheimer's disease and subcortical ischemic vascular dementia. *Journal*

of Clinical and Experimental Neuropsychology, *24*(6), 745–754. https://doi.org/10.1076/jcen.24.6.745.8399

Zannino, G. D., Perri, R., Salamone, G., DiLorenzo, C., Caltagirone, C., & Carlesimo, G. A. (2010). Manipulating color and other visual information influences picture naming at different levels of processing: Evidence from alzheimer subjects and normal controls. *Neuropsychologia*, *48*(9), 2571–2578. https://doi.org/10.1016/j.neuropsychologia.2010.05.003

Zeelenberg, R., Wagenmakers, E. J., & Rotteveel, M. (2006). The impact of emotion on perception: Bias or enhanced processing? *Psychological Science*, *17*(4), 287–291. https://doi.org/10.1111/j.1467-9280.2006.01700.x

Zimmermann, P., & Fimm, B. (2012). *Testbatterie zur Aufmerksamkeitsprüfung* [Test of Attentional Performance (TAP)] (Version 2.3). Psytest.

Appendices

Appendix A: Cognitive profile for participants with aMCI and mild AD

Mild AD group								
Participant ID	AD01	AD02	AD03	AD04	AD05	AD06	AD07	AD08
Age	74	82	78	78	75	73	79	75
Sex	m	m	m	f	m	m	f	f
Education (y)	10	10	13	8	18	8	10	10
CERAD								
MMSE Score	25	21	23	23	22	20	21	21
z-scores								
Semantic Verbal Fluency	-2.6	-1.9	-1.5	-1.3	-2.4	-1.7	-1.6	-1.7
Phonemic Verbal Fluency	-0.4	-1.6	-1.2	-1.5	-0.3	-2.1	-1.1	0.3
BNT	-0.1	-1.2	-2.1	-0.3	-1.4	0.1	0.4	-1.2
Wordlist Learning	-3.2	-2.8	-3.5	-4.5	-2.4	-3.7	-4.0	-5.1
Wordlist Recall	-3.1	-2.0	-3.1	-1.8	-2.3	-2.9	-3.8	-3.8
Wordlist Savings	-3.4	-2.3	-3.2	4.8	-2.1	-3.2	-3.2	-3.5
Discriminability	-2.6	1.2	-0.5	-0.7	-3.3	-4.1	-2.5	-1.6
Constructional Praxis	-0.7	1.2	0.9	0.0	0.6	-1.3	-0.9	-1.0
Figural Recall	-3.2	-2.0	-2.1	-2.4	-2.6	-3.1	-1.7	-2.6
Figural Savings	-2.9	-2.1	-2.1	-2.5	-2.4	-2.8	-1.7	-2.5
TMT A	-3.1	-1.4	-0.3	-2.6	-1.4	-2.7	-3.0	-2.1
TMT B	-	-	-	-	-1.4	-	-	-
TMT B/A	-	-	-	-	-0.2	-	-	-
Total score	57.7 (43)	67.6 (50)	63.6 (50)	72.0 (51)	60.2 (52)	55.5 (39)	66.5 (47)	62.2 (44)
HOSPITAL ANXIETY AND DEPRESSION SCALE (HADS-D)								
Anxiety	9	n.a.	11	4	5	9	4	2
Depression	7	n.a.	12	5	5	8	5	4
Primary symptoms in the following domains	memory, verbal fluency, attention / EF	memory, language, attention / EF	memory, language, attention / EF	memory, attention / EF	memory, verbal fluency, word finding, attention / EF	memory, verbal fluency attention / EF	memory, verbal fluency attention,	memory, attention / EF

Note. "m" = male, "f" = female; "y" = years; CERAD = Consortium to Establish a Registry on Alzheimer's Disease; "BNT" = Boston Naming Test; "TMT" = Trail Making Test; "EF" = executive function; "n.a". = data not available for this test; "-" = test not performed (e.g., due to overload or because the test could not be completed within the specified time frame and without errors); MMSE = mini-Mental-Status Examination; negative z-scores indicate below-average performance, while positive z-scores indicate above-average performance; "Total Score" = demographically corrected score, in parenthesis the raw score is given.

*Based on additional tests to assess verbal memory performance (VLMT; Helmstaedter et al., 2001) and attention (TAP; Zimmermann & Fimm, 2012).

Mild AD group							
Participant ID	AD09	AD10	AD11	AD12	AD13	AD14	AD15
Age	78	75	58	75	83	76	72
Sex	m	m	m	f	f	f	f
Education (y)	10	8	11	10	12	10	10
CERAD							
MMSE Score	24	21	24	19	27	24	24
Semantic Verbal Fluency	-2.4	-0.4	-1.8	-2.3	-2.8	-2.5	-2.0
Phonemic Verbal Fluency	-2.1	-0.9	-2.1	-1.2	-1.5	-0.9	0.0
BNT	1.5	0.2	-0.5	-3.1	-2.5	-0.5	1.5
Word List Learning	-1.7	-1.7	-1.2	-5.7	-3.3	-3.4	-3.9
Word List Recall	-1.1	-1.6	-1.6	-3.8	-1.5	-3.1	-3.9
Word List Savings	-1.0	-1.5	-2.3	n.a.	1.0	-2.9	-3.7
Discriminability	-0.4	-1.1	-2.9	-2.5	-0.8	-2.5	-1.6
Constructional Praxis	-0.6	-1.3	-4.4	-3.2	1.4	1.5	1.4
Figural Recall	-0.3	-2.6	-4.5	-2.9	-0.4	-1.5	-1.3
Figural Savings	-0.2	-2.4	-2.9	-2.8	-0.6	-1.7	-1.5
TMT A	-3.1	-	-3.6	-	-2.5	-1.0	-0.1
TMT B	-	-	-	-	-	0.3	0.6
TMT B/A	-	-	-	-	-	1.4	0.7
Total score	71.3 (55)	78.1 (61)	65.9 (57)	47.2 (29)	67.0 (48)	65.5 (47)	69.2 (52)
HOSPITAL ANXIETY AND DEPRESSION SCALE (HADS-D)							
Anxiety	3	11	4	5	13	5	0
Depression	4	10	8	3	10	0	0
Primary symptoms in the following domains	memory, verbal fluency, attention / EF	memory, attention / EF	memory, constructional praxis, verbal fluency, attention / EF	memory, language, attention / EF	memory, language, attention / EF	memory, verbal fluency	memory, verbal fluency

Note. "m" = male, "f" = female; "y" = years; CERAD = Consortium to Establish a Registry on Alzheimer's Disease; "BNT" = Boston Naming Test; "TMT" = Trail Making Test; "EF" = executive function; "n.a." = data not available for this test; "-" = test not performed (e.g., due to overload or because the test could not be completed within the specified time frame and without errors); MMSE = Mini-Mental-Status Examination; negative z-scores indicate below-average performance, while positive z-scores indicate above-average performance; "Total Score" = demographically corrected score, in parenthesis the raw score is given.

aMCI group								
Participant ID	MCI01	MCI02	MCI03	MCI04	MCI05	MCI06	MCI07	MCI08
Age	63	79	79	78	68	70	65	62
Sex	m	m	m	f	f	m	m	m
Education (y)	10	10	10	8	9	10	10	10
CERAD								
MMSE Score	27	26	28	28	28	28	27	28
z-scores								
Semantic Verbal Fluency	-1.2	-1.4	-0.8	0.8	-1.8	-0.8	2.4	1.5
Phonemic Verbal Fluency	-0.2	-1.1	-0.8	0.7	-1.9	-0.5	-0.1	0.5
BNT	-0.3	0.1	-0.7	1.9	-0.7	-0.1	1.2	1.1
Word List Learning	-2.8	-1.7	-2.6	-1.3	-1.4	-0.8	-0.8	-1.6
Word List Recall	-2.3	-0.1	-1.5	-2.3	-0.8	0.0	-0.7	-0.9
Word List Savings	-3.2	1.3	-0.6	-2.4	-0.8	1.2	-1.4	1.1
Discriminability	-1.4	1.2	-1.6	0.9	-1.0	-0.6	1.0	0.9
Constructional Praxis	-0.8	1.1	1.1	0.0	-0.2	1.0	-0.8	0.9
Figural Recall	-1.0	-0.7	-0.3	-1.4	-1.4	1.6	-1.4	-0.5
Figural Savings	-0.7	-0.9	-0.5	-1.6	-1.3	0.9	-1.1	-0.6
TMT A	-0.5	-0.1	-1.0	0.1	-0.4	1.3	-0.1	0.6
TMT B	-	0.7	-	0.2	-2.1	1.9	1.2	2.0
TMT B/A	-	0.8	-	0.1	-1.9	0.6	-	-
Total score	71.4 (60)	79.6 (63)	72.6 (56)	95.0 (74)	81.8 (65)	85.7 (72)	93.1 (81)	91.1 (80)
HOSPITAL ANXIETY AND DEPRESSION SCALE (HADS-D)								
Anxiety	6	2	4	5	4	8	2	3
Depression	9	3	3	4	0	6	5	1
Primary symptoms in the following domains	memory, attention / EF	memory, verbal fluency	memory, attention / EF	memory	memory, verbal fluency, attention / EF	memory*	memory	memory, attention*

*Based on additional tests to assess verbal memory performance (VLMT; Helmstaedter et al., 2001) and attention (TAP; Zimmermann & Fimm, 2012).

aMCI group							
Participant ID	MCI09	MCI10	MCI11	MCI12	MCI13	MCI14	MCI15
Age	84	70	73	76	82	77	70
Sex	m	m	m	f	f	f	m
Education (y)	18	12	10	10	10	10	16
CERAD							
MMSE Score	28	26	29	27	26	28	27
z-scores							
Semantic Verbal Fluency	-1.9	-1.3	-0.8	-0.2	-0.5	-0.9	-0.4
Phonemic Verbal Fluency	-2.2	-1.9	-0.9	-0.1	0.5	-1.2	0.3
BNT	1.0	-1.1	-0.8	-0.5	-0.9	-1.1	-2.0
Word List Learning	-0.4	-0.4	-0.7	-2.5	-0.7	-4.0	1.0
Word List Recall	0.0	-0.7	-1.8	-3.8	-0.9	-1.0	1.2
Word List Savings	0.9	-1.3	-2.2	-3.4	-0.6		0.1
Discriminability	1.0	-0.7	-0.5	-2.5	0.9	-0.8	0.8
Constructional Praxis	0.7	0.9	1.0	1.5	-0.1	-1.0	0.6
Figural Recall	1.3	-2.5	1.7	-1.8	-2.1	-2.4	-2.4
Figural Savings	1.0	-2.3	1.0	-1.9	-2.3	-2.4	-2.1
TMT A	0.4	-0.3	0.6	-0.8	-1.1	-2.5	-0.9
TMT B	0.0	-1.6	-0.1	-	-	-	-1.3
TMT B/A	-0.3	-1.5	-0.6	-	-	-	-0.6
Total score	81.1 (70)	81.9 (70)	80.7 (66)	79.5 (61)	89.5 (69)	75.8 (57)	93.3 (85)
HOSPITAL ANXIETY AND DEPRESSION SCALE (HADS-D)							
Anxiety	4	3	9	3	11	12	5
Depression	4	1	5	1	7	6	8
Primary symptoms in the following domains	verbal fluency	memory, language, attention / EF	memory	memory, attention / EF	memory, attention / EF	memory, attention / EF	memory, word finding, attention / EF

Note. "m" = male, "f" = female; "y" = years; CERAD = Consortium to Establish a Registry on Alzheimer's Disease; "BNT" = Boston Naming Test; "TMT" = Trail Making Test; "EF" = executive function; "n.a." = data not available for this test; "-" = test not performed (e.g., due to overload or because the test could not be completed within the specified time frame and without errors); MMSE = Mini-Mental-Status Examination; negative z-scores indicate below-average performance, while positive z-scores indicate above-average performance; "Total Score" = demographically corrected score, in parenthesis the raw score is given.

Appendix B: Stimulus list

Mean ratings of psycholinguistic variables based on the rating scale by the Automatically Generated Affective Norms for German Lemmas (Köper & Walde, 2016) spanning from 1 to 10.

Object naming	*Psycholinguistic variables*					
Items	abstractness / concreteness	arousal	imageability	valence	no. of syllables	word accent
Apfel	7.949	2.925	6.653	6.101	2	1
Beule	6.603	5.109	6.733	3.202	2	1
Bombe	6.691	8.274	7.402	3.165	2	1
Bürste	6.997	3.060	6.067	4.858	2	1
Engel	6.233	4.982	6.909	6.030	2	1
Esel	6.843	3.602	7.214	5.568	2	1
Gabel	7.209	2.400	6.333	5.142	2	1
Geige	7.100	3.812	7.050	6.345	2	1
Geschenk/umg. Pakerl	4.944	5.428	5.920	8.195	2	2/1
Gewehr/umg. Büchse	7.540	5.697	7.660	3.423	2	2/1
Harfe	7.268	3.163	7.111	6.952	2	1
Hase	7.484	3.115	6.515	6.130	2	1
Haube	6.538	3.282	5.954	5.053	2	1
Insel	6.622	3.927	6.383	6.684	2	1
Käfig	7.504	3.957	7.491	4.196	2	1
Katze	7.953	4.354	7.391	5.594	2	1
Kirche	5.865	4.421	6.815	4.388	2	1
Kirsche	7.496	3.708	7.778	6.252	2	1
Klavier/Flügel	6.972	4.548	7.410	6.221	2	2/1
Koffer	7.495	3.501	7.858	5.039	2	1
Krücke(n)	5.583	4.203	5.364	3.861	2	1
Kürbis	7.835	3.721	7.662	5.381	2	1
Lupe	4.995	3.335	6.031	4.653	2	1
Muschel	8.234	2.466	7.512	5.747	2	1
Nadel	7.278	3.526	6.399	4.209	2	1

(*Continued*)

(Continued).

Object naming	*Psycholinguistic variables*					
Items	abstractness / concreteness	arousal	imageability	valence	no. of syllables	word accent
Narbe	6.405	5.325	6.108	3.713	2	1
Nase	6.638	3.315	6.754	5.076	2	1
Palme	4.805	4.575	5.346	6.001	2	1
Panzer	7.396	6.305	7.792	3.679	2	1
Peitsche	6.348	6.463	6.758	3.410	2	1
Pinsel	7.014	2.775	6.005	5.966	2	1
Puppe	7.781	5.179	7.902	5.852	2	1
Schere	7.034	4.206	6.535	3.669	2	1
Schlange	6.942	4.704	6.977	3.502	2	1
Schraube	6.06	2.557	5.430	4.521	2	1
Sonne	6.548	3.791	8.092	7.433	2	1
Spinne	6.979	5.583	7.439	4.126	2	1
Spritze	7.260	5.028	6.199	3.150	2	1
Stempel	5.842	2.870	4.425	4.856	2	1
Teufel	4.542	7.343	5.365	2.655	2	1
Unfall	5.656	9.043	7.080	2.382	2	1
Urne	7.176	3.422	6.898	3.658	2	1
Vogel	8.117	3.910	7.691	5.356	2	1
Würfel	6.395	2.908	6.560	4.819	2	1
[Zäpfchen]	6.786	4.401	5.542	4.397	2	1
mean values	***6.84 (0.82)***	***4.27 (1.50)***	***6.80 (0.81)***	***4.95 (1.34)***	-	-

Action naming	*Psycholinguistic variables*					
Items	abstractness / concreteness	arousal	imageability	valence	no. of syllables	word accent
betteln	4.706	5.418	5.905	3.832	2	1
brennen	5.264	5.686	5.828	4.265	2	1
essen	5.613	5.044	7.480	6.284	2	1
fallen	5.333	4.242	5.857	4.280	2	1
[feiern]	3.869	5.978	5.633	7.079	2	1
fönen	5.840	4.204	6.104	4.799	2	1
frieren	4.707	4.775	6.014	4.114	2	1
gehen	4.369	4.408	5.414	5.881	2	1
[golfen]	6.657	3.642	6.967	5.634	2	1
[heben]	5.396	2.797	5.617	5.817	2	1
heulen	4.651	6.923	6.301	2.895	2	1
kämpfen	4.672	6.789	6.224	4.360	2	1
klatschen	6.086	4.667	6.609	5.347	2	1
küssen	6.102	5.928	8.319	6.485	2	1
lachen	4.844	5.502	6.667	5.677	2	1
laufen	5.319	3.450	5.027	4.982	2	1
lesen	4.503	4.021	5.637	7.372	2	1
nähen	5.824	3.905	6.029	5.184	2	1
rauchen	6.148	5.504	6.688	4.308	2	1
[rechnen]	4.210	4.231	3.241	4.758	2	1
regnen	5.841	4.503	6.874	5.023	2	1
[sabbern]	5.009	6.352	6.131	3.884	2	1
[schenken]	3.204	4.377	5.148	7.666	2	1
schießen	5.398	6.447	6.581	3.842	2	1
schimpfen	4.267	5.188	5.605	2.258	2	1
schlafen	5.919	4.548	6.878	5.807	2	1
[schlagen]	4.986	5.724	6.357	3.938	2	1
schreiben	4.759	4.040	4.871	6.382	2	1
segeln	5.922	4.247	6.460	6.046	2	1

(*Continued*)

(Continued).

Action naming	*Psycholinguistic variables*					
Items	abstractness / concreteness	arousal	imageability	valence	no. of syllables	word accent
[(durch-)sieben]	5.556	4.669	5.423	1.819	2	1
singen	5.183	4.813	6.141	6.826	2	1
sitzen	5.591	3.052	6.473	4.994	2	1
[sonnen]	5.608	3.407	7.167	6.700	2	1
spielen	5.238	4.719	5.751	5.960	2	1
[spucken]	5.299	5.625	6.109	2.322	2	1
stehlen	4.170	5.849	5.767	3.960	2	1
streiten	4.213	6.268	4.817	4.267	2	1
tanzen	6.279	5.733	7.959	6.554	2	1
tauchen	5.236	4.122	6.029	5.638	2	1
tragen	5.024	4.363	5.819	5.929	2	1
trinken	5.957	4.262	6.765	5.893	2	1
wandern	5.209	3.395	6.836	5.942	2	1
weinen	5.032	6.737	7.026	4.288	2	1
zeigen	3.994	4.348	4.252	5.563	2	1
ziehen	4.227	3.951	5.135	4.133	2	1
mean values (SD)	***5.09 (0.73)***	***4.89 (0.98)***	***5.99 (0.88)***	***5.07 (1.21)***	-	-

Positive	*Psycholinguistic variables*					
Items	abstractness / concreteness	arousal	imageability	valence	no. of syllables	word accent
Apfel	7.949	2.925	6.653	6.101	2	1
Engel	6.233	4.982	6.909	6.030	2	1
Geige	7.10	3.812	7.050	6.345	2	1
Geschenk/umg. Pakerl	4.944	5.428	5.920	8.195	2	2/1
Harfe	7.268	3.163	7.111	6.952	2	1
Hase	7.484	3.115	6.515	6.130	2	1
Insel	6.622	3.927	6.383	6.684	2	1
Kirsche	7.496	3.708	7.778	6.252	2	1
Klavier/Flügel	6.972	4.548	7.410	6.221	2	2/1
Palme	4.805	4.575	5.346	6.001	2	1
Sonne	6.548	3.791	8.092	7.433	2	1
essen	5.613	5.044	7.480	6.284	2	1
küssen	6.102	5.928	8.319	6.485	2	1
lesen	4.503	4.021	5.637	7.372	2	1
schreiben	4.759	4.040	4.871	6.382	2	1
segeln	5.922	4.247	6.460	6.046	2	1
singen	5.183	4.813	6.141	6.826	2	1
spielen	5.238	4.719	5.751	5.960	2	1
tanzen	6.279	5.733	7.959	6.554	2	1
mean values (SD)	***6.19 (1.08)***	***4.17 (0.85)***	***6.69 (0.94)***	***6.59 (0.58)***	-	-

Negative	*Psycholinguistic variables*					
Items	abstractness / concreteness	arousal	imageability	valence	no. of syllables	word accent
Beule	6.603	5.109	6.733	3.202	2	1
Bombe	6.691	8.274	7.402	3.165	2	1
Gewehr/umg. Büchse	7.540	5.697	7.66	3.423	2	2/1
Narbe	6.405	5.325	6.108	3.713	2	1
Panzer	7.396	6.305	7.792	3.679	2	1
Peitsche	6.348	6.463	6.758	3.410	2	1
Schere	7.034	4.206	6.535	3.669	2	1
Schlange	6.942	4.704	6.977	3.502	2	1
Spritze	7.260	5.028	6.199	3.150	2	1
Teufel	4.542	7.343	5.365	2.655	2	1
Unfall	5.656	9.043	7.080	2.382	2	1
Urne	7.176	3.422	6.898	3.658	2	1
betteln	4.706	5.418	5.905	3.832	2	1
brennen	5.264	5.686	5.828	4.265	2	1
heulen	4.651	6.923	6.301	2.895	2	1
kämpfen	4.672	6.789	6.224	4.36	2	1
schießen	5.398	6.447	6.581	3.842	2	1
schimpfen/tadeln	4.267	5.188	5.605	2.258	2	1
stehlen	4.17	5.849	5.767	3.96	2	1
mean values (SD)	***5.85 (1.31)***	***5.93 (1.36)***	***6.35 (0.96)***	***3.32 (0.48)***	-	-

Neutral			*Psycholinguistic variables*			
Items	abstractness / concreteness	arousal	imageability	valence	no. of syllables	word accent
Bürste	6.997	3.06	6.067	4.858	2	1
Esel	6.843	3.602	7.214	5.568	2	1
Gabel	7.209	2.4	6.333	5.142	2	1
Haube	6.538	3.282	5.954	5.053	2	1
Katze	7.953	4.354	7.391	5.594	2	1
Kirche	5.865	4.421	6.815	4.388	2	1
Koffer	7.495	3.501	7.858	5.039	2	1
Krücke(n)	5.583	4.203	5.364	3.861	2	1
Kürbis	7.835	3.721	7.662	5.381	2	1
Lupe	4.995	3.335	6.031	4.653	2	1
Nase	6.638	3.315	6.754	5.076	2	1
Schraube	6.060	2.557	5.430	4.521	2	1
Stempel	5.842	2.870	4.425	4.856	2	1
Vogel	8.117	3.910	7.691	5.356	2	1
Würfel	6.395	2.908	6.56	4.819	2	1
fönen	5.840	4.204	6.104	4.799	2	1
klatschen	6.086	4.667	6.609	5.347	2	1
lachen	4.844	5.502	6.667	5.677	2	1
laufen	5.319	3.45	5.027	4.982	2	1
nähen	5.824	3.905	6.029	5.184	2	1
regnen	5.841	4.503	6.874	5.023	2	1
sitzen	5.591	3.052	6.473	4.994	2	1
tauchen	5.236	4.122	6.029	5.638	2	1
zeigen	3.994	4.348	4.252	5.563	2	1
ziehen	4.227	3.951	5.135	4.133	2	1
mean values (SD)	***6.15 (1.10)***	***3.80 (0.85)***	***6.27 (0.96)***	***5.04 (0.40)***	-	-

Note. SD = standard deviation; word accent: 1 = trochaic, 2 = jambic; umg. (= "umgangssprachlich") = colloquial variant. The items in square brackets are those that have been excluded due to an excessive number of naming errors. The classification based on the valence ratings was carried out according to the following grouping: positive (> 6.0), negative (< 4.0), and neutral (> 4.3 and < 5.7).