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Original Article

Speech Audiometry Tests in Noise Are Impaired in Older Patients with Mild Cognitive Impairment: A Pilot Study

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OBJECTIVE: Mild cognitive impairment (MCI) is a frequent condition in the older population; its early diagnosis might be particularly important for the prevention of dementia onset. In particular, the aim of this study is to evaluate whether speech recognition in noise might be impaired in older patients with MCI compared with normal older individuals.

MATERIALS and METHODS: On the whole, 48 subjects were enrolled into the present study: 16 older patients with MCI, 16 older subjects without cognitive impairment (controls), and 16 normally hearing young individuals. All subjects underwent speech audiometry in noise in order to evaluate the effect of different types of masking: two kinds of energetic masking, stationary and fluctuating noise, and a kind of typical informative masking, consisting of continuous discourse.

RESULTS: The signal-to-noise ratio (S/N), expressed in dB, needed for speech reception threshold (SRT) in noise was worse in older patients affected by MCI, compared with older controls. The presence of masking likely affected the performance of both elderly controls and MCI patients; however, elderly controls had better performance with informative masking (CoDi) than MCI patients.

CONCLUSION: Speech audiometry tests in noise are impaired in MCI older patients, and this could indicate a particular decline in functions associated with selective attention in these individuals. If confirmed in a larger sample of patients, these simple tests might contribute to the early identification of MCI patients.

KEY WORDS: Speech audiometry in noise, auditory tests, mild cognitive impairment

INTRODUCTION

Mild cognitive impairment (MCI) defines a condition, typical of elderly subjects, that does not meet the criteria for dementia but, more often than in normal aging, may precede dementia onset. Several criteria and subtypes of MCI have been proposed [1-3]. Originally, the concept of MCI emphasized memory impairment as a precursor state for Alzheimer disease (AD). Subsequently, it was recognized that the etiology, clinical presentation, and prognosis of MCI might be heterogeneous [3-5], and the definition of MCI was expanded to other cognitive domains [6-8]. The conversion of MCI to dementia depends on the interaction of several factors, including genetic predisposition, comorbidity, environmental factors, and cognitive reserve of single individuals. The conversion rate is variable; some authors reported that 60% of MCI patients might be stable in the next 3 years [9], while others found that up to 40% might even return to normal during follow-up [10]. However, a statement of the American Academy of Neurology [11] recommends the early detection of MCI because of its increased risk of conversion to dementia; indeed, the early diagnosis might be particularly important for the prevention of dementia.

Aging is usually associated with sense organ impairment, as a consequence of metabolic and cardiovascular disorders, drugs, and noise exposure. The consequence of age-related hearing impairment on the perception of sounds can be partially compensated for by the plasticity of the central nervous system (CNS). Sometimes, these mechanisms may fail, thus reducing the identification and recognition of complex sounds, particularly of speech.

Presbycusis, the hearing impairment typical of aging, has a prevalence of about 80% [1-10]. The evidence that presbycusis is associated with a reduction in speech perception suggests that central auditory pathways are also involved in its pathogenesis [12, 13]. In optimal listening conditions (silent environment, nondegraded speech signal, low reverberation), the scores obtained in speech audiometry tests by old subjects are similar to those obtained by young individuals with similar high-frequency hearing loss [14]. On the contrary, in challenging acoustic conditions, older subjects often have difficulties in understanding speech content. Starting from

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the sixth decade, significant worsening can be observed in speech recognition scores, when signal is degraded (filtered or accelerated) or masked by noisy background. Compared to an adult with similar hearing loss, an elderly person needs higher levels of speech or lower levels of masker to obtain the same (50%) speech recognition score. In other terms, as already reported, old people require an elevation in the signal-to-noise ratio (S/N) of 5 to 8 dB [15-17] with respect to the junior counterpart. The origin of such hearing difficulties in the elderly has been much debated, and it has been attributed to both peripheral disorders (75%) and central disorders (30%) [17, 18]. Peripheral disorders are related to cochlear damage, while central disorders are in relation to specific hearing functions (i.e., binaurality, speech neural coding) and supramodal functions, such as the ability to retain new information, poor short-term memory, and attentive disorders. So far, most of the studies have evaluated the role of hearing loss on MCI, while only a few have investigated and focused on speech perception in MCI subjects.

In the present study, we then evaluated whether the consequences of hearing loss associated with aging among speech perception might be more relevant in older patients with MCI in comparison with cognitively normal controls. By administrating speech material in a noisy background, we evaluated the effect of different types of masking, including two kinds of energetic masking (stationary and fluctuating noise) and typical informative masking consisting of continuous discourse.

MATERIALS and METHODS

Subjects

A total of 48 subjects were enrolled into the present study:

1. Sixteen elderly subjects with amnesic MCI (mean age: 78.6 yrs) who had been evaluated as outpatients at the memory clinic of the Operative Unit of Geriatrics for subjective/objective memory complaints. MCI was defined as the presence of short-/long-term memory impairment, with/without impairment in other single or multiple cognitive domains, in an individual who did not meet the standardized criteria for dementia[6, 8]. We also required that the patient with MCI would be still independent in the activities of daily living (ADLs). All MCI patients underwent the Mini-Mental State Examination (MMSE), Alzheimer's Disease Assessment Scale (ADAS), Geriatric Depression Scale (GDS), routine clinical chemistry (to exclude secondary forms of MCI), EKG, and brain CT scan. When necessary, MCI patients were further evaluated by using specific neuropsychological tests, including Rey test, Raven matrices, Trail making test, Digit span, Clock-drawing test, Babcock tale, and Frontal Assessment Battery, and cerebral SPECT. Cognitive performance was within the normal limits (adjusted MMSE>24/30) in 15/16 patients. Mild depressive symptoms were present in 50% of patients (GDS>5/15). All patients were basically independent in basic ADLs (BADLs) and instrumental ADLs (IALDs).
2. Sixteen elderly subjects without cognitive impairment (mean age: 76 yrs) as an elderly control group. All of these subjects had been enrolled at the audiology department and were matched to MCI subjects for age and hearing loss, within ±2 years and ±5 dB as pure tone average (PTA: 0.5 to 2 kHz) threshold, respectively. They were free from memory complaints and cognitive deficits; their mean MMSE score was 27.8±2.
3. Sixteen normally hearing young individuals (mean age: 22.5 yrs) furnished the normative data for the speech audiometry tests.

Table 1. List of 5 meaningful sentences in Italian language

La macchina funziona male
Franco è andato via di casa
Ieri hai comprato poco latte
L'idraulico ripara il guasto
Francesca è incinta di nuovo

Our research was conducted in compliance with the Helsinki Declaration (2008). Although informed consent was not required because this study was observational and did not affect patient care in any way, all subjects were informed about the research project during the first visit and gave their written consent in order to participate to the study.

Auditory Tests

All subjects underwent the following tests:

a) Pure tone air and bone threshold audiometry calibrated according to ISO 9001 in a silent booth.
b) Speech audiometry in noise.

The latter was conducted by presenting the primary speech signal embedded into three different acoustic backgrounds *a)* speech noise (SpNo) consisting of stationary noise with the same spectral content of speech; *b)* ICRA (International Collegium of Rehabilitative Audiology-) noise, spectrally similar to SpNo but with the same temporary envelope of speech; and *c)* continuous discourse (CoDi), consisting of a male voice reading simple text. All of these backgrounds will be hereafter defined as "maskers," while the notation of informative masker is reserved for CoDi.

Speech audiometry in noise was performed in a free field, within a soundproof booth (2x2x3 m).

The speech signal consisted of 12 lists, each with 20 meaningful sentences (an example list can be found in Table 1) in Italian language.

The signal was presented at the better ear PTA threshold level. Masking was presented at 35-45 dB above the better ear PTA threshold to the subjects of the two elderly groups. Masking was presented at a fixed intensity of 55 dB to the normally hearing group.

These intensity levels allowed the masking signal to be above the individual hearing threshold for most of its frequency spectrum (up to 4 kHz). Sentences and masking were delivered from two loudspeakers (20x30 cm) placed frontally at a distance of 1 meter from the subject's head. Each subject received masking conditions and the list of sentences in random order.

For each masking condition, speech recognition threshold (SRT), corresponding to the 50% of correctly repeated sentences, was obtained by means of an adaptive up-down procedure with 2-dB steps, up to 7-8 reversals. The total duration of the examination ranged from a minimum of 20 minutes to a maximum of 30, comprising the time needed by each subject to understand the whole task.

Statistical Analysis

Two-way analysis of variance (ANOVA) was used to compare the effects on the SRT of subject groups and maskers, by using a SPSS system operating on a Windows Base System (SPSS Inc., Chicago, Illinois).The differences between pairs of data were evaluated by t-tests. Linear regression analysis was used to test the dependency between age and masked SRT. The level of significance was considered $p<0.05$.

RESULTS

Audiometric data of the two elderly groups showed an average PTA (0.5-2 KHz) of 24.7 +/-12.6 dBHL (better ear) and 30.3 +/-14.9 dBHL (worst ear) for the MCI group and 21.1 +/-10.5 dBHL (better ear) and 25.7 +/-13.3 dBHL (worst ear) for the elderly control group.

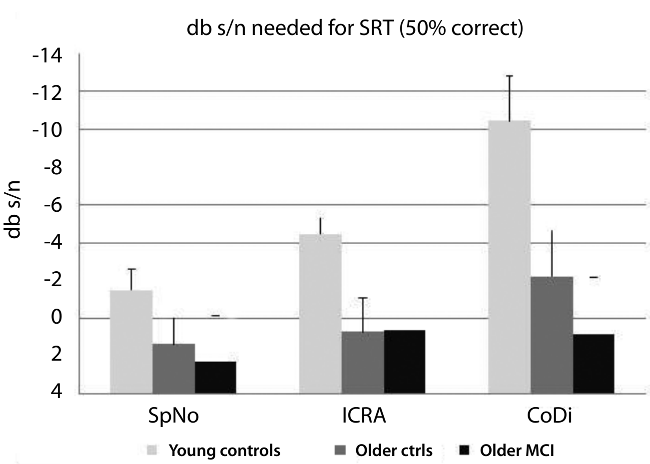

Figure 1. Signal-to-noise (S/N) ratio (in dB) needed for speech reception threshold (SRT) in the three groups while listening in 3 different background noises. MCI subjects only differed from older ctrs for the CoDi condition ($p<0.001$). (An S/N ratio towards negative dB values means better performance)

Figure 1 reports the mean values of S/N ratio in dB, required for the SRT, obtained in the two elderly groups and the normal hearing group. An S/N ratio towards negative dB values means better performance. The data clearly indicate that young people consistently improved the SRT by changing the masker from stationary (SpNo) to ICRA and CoDi, with a maximal advantage of about 8 dB. Compared to the young group, both of the elderly groups showed a worse SRT with SpNo and also failed to take strong advantage of the ICRA and CoDi maskers. Two-way ANOVA revealed a significant effect on the change in dB S/N ratio due to both factors: i.e., groups ($F=134$, $p<0.0001$) and maskers ($F=59.3$, $p<0.0001$). A significant interaction ($p<0.0001$) was also found, indicating that the combined effect of the two factors was not purely additive.

A further analysis with paired data showed that both elderly groups had worse performance than the normal hearing group in all of the 3 masking conditions. In addition, a significant difference in performance between the two elderly groups was found but only when CoDi was used as masker (t-test, $p<0.001$). With CoDi, the MCI subjects showed the worst performance requiring a S/N ratio of 3 dB higher than their age-matched controls to reach the SRT. In contrast, these two groups showed essentially the same performance when using either SpNo or ICRA.

In order to evaluate if the three maskers used had a different influence in relation to the subjects' age and whether this influence was different in the two elderly groups, the values of the individual SRT were analyzed by regression analysis. The hypothesis was that patients with MCI had the worst performance for age-dependent deterioration of cognitive hearing pathways in relation to the evolutionary nature of dementia. Figure 2 reports the data for the control elderly group; in this case, age showed a significant effect in worsening the performance but only for the condition of informative masking (CoDi), while the SRT masked by SpNo and ICRA did not show any significant age-related changes. The adverse effect on the SRT, masked by CoDi and explained by age, was estimated in 2.8 dB S/N ratio per decade. Figure 3 shows the results obtained from MCI subjects; the SRT significantly worsened with age in all three masking conditions tested. Further, this effect in terms of S/N ratio was estimated as 3.3 dB, 3.8 dB, and 3.9 dB for each decade of elderly subjects, respective-

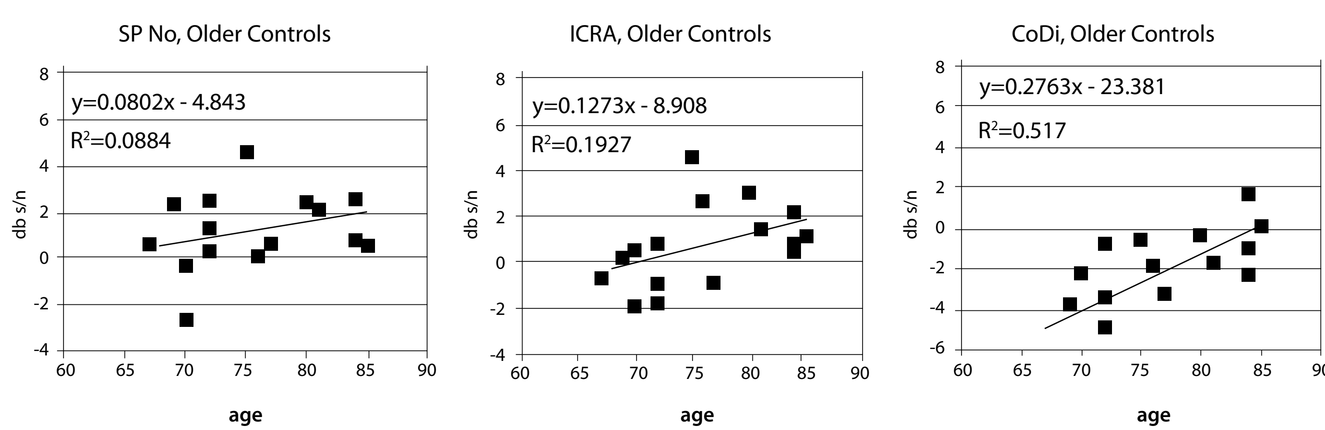

Figure 2. Linear regression analysis for the dB S/R variation vs age in elderly controls. Speech recognition in noise significantly worsened with age only when continuous discourse (CoDi) was used as the masker ($p<0.01$). (An S/N ratio towards negative dB values means better performance)

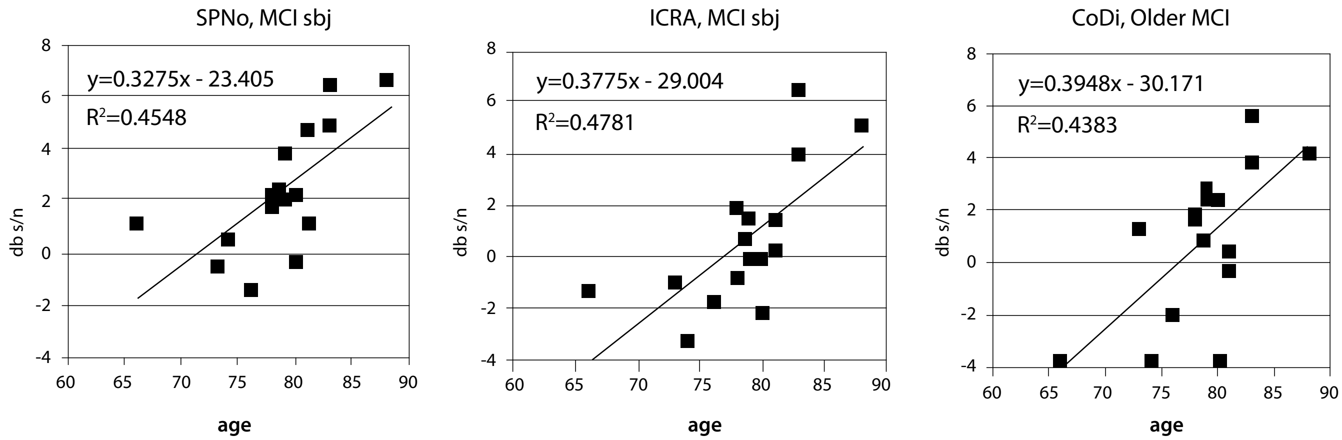

Figure 3. Linear regression analysis for the dB S/R variation vs age in older patients with MCI. Speech recognition in noise significantly worsens with age with all the three maskers ($p<0.01$). (An S/N ratio towards negative dB values means better performance)

ly, for the three types of masking. This indicates that compared to their age-matched counterparts, the MCI patients suffer from a more consistent but more pervasive age effect by informative masking (2.8 vs. 3.8 dB S/N), as it also manifests with the two noise maskers (SpNo and ICRA). The values indicate that to preserve a constant speech recognition rate, these patients need an improvement of 3 to 4 dB in S/N for each decade of age above 65 years.

DISCUSSION

It is well known that aging is associated with significant declines in hearing thresholds, as well as in the ability to identify and remember spoken words; there is also evidence that supra-threshold functions, such as frequency, intensity, and temporal discrimination, may be impaired in older listeners and that these impairments may adversely affect speech perception, especially under degraded listening conditions [19-21].

An association between older subjects affected by MCI and hearing impairment has been described, and particularly, hearing impairment has also been indicated as a contributory factor to cognitive decline in MCI patients [1-21]. Nonetheless, so far, most of the studies have evaluated the role of hearing threshold on MCI, while only few have investigated speech perception in MCI [1-21]. The aim of this study was to specifically assess whether elderly patients with MCI had particular difficulties in speech perception in noisy conditions, compared to age-/hearing-matched controls with normal cognitive functions.

In particular, from the analysis of our data, it is possible to observe that:

a) compared to stationary SpNo, the fluctuating ICRA noise significantly improved the performance in normal hearing subjects, while there were no differences in elderly individuals.
b) compared to stationary SPNo, informative masking (CoDi) significantly improved the performance in elderly controls, (although to a lesser degree than in young subjects) but not in elderly MCI subjects.

The latter finding suggests that MCI subjects had a particular decline in speech perception in noisy conditions and then in cognitive function associated with selective attention. This observation confirms the hypothesis that in the elderly, the central auditory processing dedicated to speech perception might be particularly sensitive to temporally fluctuating noise and informative masking, and this seems to be more evident in subjects with MCI. In particular, we found that in patients with MCI, these acoustic conditions may highlight defects of auditory processing and selective attention. Speech recognition in noise was generally worse in both elderly groups compared with young individuals. The low tolerance of noise during speech recognition is a common finding in subjects with age-related hearing loss, and the cause may be related to defects of central auditory processing[22-39]. As shown by our data, while normal young subjects do benefit from temporal fluctuation of ICRA noise and yet more consistently from the masking produced by continuous discourse, elderly subjects seem less capable of taking advantage of the masking envelope discontinuities, and this was much more evident in MCI subjects. In young subjects, the SRT improved 3 dB with ICRA, because the fluctuation in amplitude of noise allowed some portions of the speech signal to "escape" from masking. The performance of the two older groups did not differ when the masking was steady or fluctuating noise, but the cognitively normal group performed better than the MCI group when the masking was informative.

Finally, we have to acknowledge some important limitations of the study. First, even if it is clear that the results of this study have a statistical value, the sample size was small, and our results then need to be replicated in larger samples of MCI older individuals. This would be particularly useful in order to define the sensitivity and specificity of speech perception in MCI patients. Second, we did not include data about the evolution of these MCI patients over time. This aspect is important, since it might definitively confirm the utility of speech audiometry in noise not only in detecting MCI but also in identifying, among all MCI cases, those evolving into dementia. This point, in particular, should be addressed in a future longitudinal study. Third, anticholinergic medications in elderly patients are known to affect certain brain functions [40]. Although none of our MCI patients was taking anticholinergic drugs at the time of the study, several types of drugs have potential anticholinergic activity. This specific point should be taken into consideration when the pilot study will be possibly expanded.

In conclusion, in the MCI group, speech perception degrades significantly with age when using all three maskers employed. On the contrary, in the elderly control group, age deterioration occurs with a less pronounced rate, and most importantly, it is significant only with the informative masker. This allows us to confirm the hypothesis that the MCI group has an age-related dysfunction of central processing, which could be related to the process leading to dementia. This hypothesis is in accordance with the observation of other authors[41-43]. Since the early identification of patients with MCI may allow an earlier clinical approach, it would be particularly useful to have a reliable and practical instrument to identify MCI patients; in this sense, speech audiometry in noise might represent a useful and easy-to-access tool.

Ethics Committee Approval: The research was conducted in compliance with the Helsinki Declaration (2008).

Informed Consent: All subjects were informed about the research project during the first visit and gave their written consent in order to participate to the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.P., C.A.; Design - S. P., G.Z.; Supervision - S.P., G.Z.; Materials - S.P., A.C, L.M., C.S.; Data Collection and/or Processing - A.C., C.S., C.A.; Analysis and/or Interpretation - A.C., C.A, S.P., G.Z.; Literature Review - A.C., G.Z.; Writing - A.C., G. Z., S.P., L.M., C.S.; Critical Review - C.A.

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