



Reduced Lexical Access in Individuals with Subjective Cognitive Decline

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Abstract

Subjective memory complaints may be an early marker of degenerative diseases; however, it may also be a normal aging process. Discovering a cognitive-language task that can well detect subtle changes in individuals with Subjective Cognitive Impairment (SCI) is crucial at the preventive medicine level, which emphasizes early detection of groups at high risk of cognitive impairment. Twelve patients with amnesic mild cognitive impairment, 12 with SCI, and 12 age- and education-matched Normal Elderly (NE) performed concrete word definition tasks. Regardless of word frequency, the mean score for word definition was significantly lower in the order of NE, SCI, and aMCI. A significant difference was found in the prevalence of definition types among the three groups. The prevalence of error types observed during word definition differed between the three groups. In conclusion, a definition task may provide richer information on the semantic-lexical impairment in SCI.

Keywords: Semantics; Subjective cognitive impairment; Definition; Early detection

Introduction

As aging progresses, concern about patients with degenerative dementia is expanding to include elderly people in the pre-clinical stage, and research on patients with Subjective Cognitive Impairment (SCI) has become common [1]. Individuals with SCI demonstrate normal range abilities in objective memory tasks but subjectively complain of memory impairment [2]. Recently, SCI has become a field of interest because it has a significant correlation with neuropathological changes observed in postmortem brain tissue, cognitive decline, and dementia [3]. Subjectively complaining of memory problems may be an early marker of degenerative diseases that cause cognitive disorder; however, it may also be a normal aging process or a secondary symptom caused by depression or psychological stress [4]. Individuals with SCI are reported to have a four-fold higher risk of developing dementia compared to Normal Elderly (NE) people [5], and they are considered a high-risk group with cognitive disorder because it is associated with long-term neurodegenerative diseases. However, because these patients often show normal performance on comprehensive neuropsychological tests [6], it is important to select a task that can better detect subtle changes related to SCI and use these as data for early detection. People who subjectively complain to have memory problems report that they “cannot think of names quickly.” This pattern is owing to weakening connections between the semantic and phonological nodes. A task that evaluates the naming ability can be used to observe these changes. Several tasks including verbal fluency, confrontation naming, picture description, and word definition are used to evaluate naming ability. Among these tasks, confrontation naming and verbal fluency examine semantic retrieval ability at the word level [7]; therefore, they are limited in demonstrating subtle changes in cognition and language [8].

Conversely, the word definition task requires knowledge accessing the mental-lexicon and a higher cognitive linguistic process, which is knowledge of what definition is [9]. Among the tasks, word definition places a relatively higher demand on the higher cognitive linguistic process, which requires the effective manipulation of the semantic system via the integration of primary linguistic knowledge and cognitive functions [10].

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In word definition tasks, describing the meanings of words, the subjects' responses are analyzed both quantitatively (i.e., number of semantic concepts produced for word definition) and qualitatively (i.e., whether the semantic features are core or supplementary meanings) aspects [11]. Therefore, the definition tasks provide a lot of information about the level of subjects' semantic processing. Despite the usefulness of word definition tasks in demonstrating subtle semantic degeneration, few studies have utilized these tasks. In addition, studies have been conducted on NE, AD patients, and mild cognitive impairment [12-15], whose performance in neuropsychological assessment or neuropathological change is strictly classified; however, no study has extended to SCI in the pre-clinical stage.

Therefore, we examined performance on a word definition task for each process, from normal aging to SCI and mild cognitive impairment, by analyzing word frequency, type of definition, and error type. We aim to determine whether the use of semantic knowledge and semantic processing at the stage of subjective complaints of memory problems is discriminatively different from NE and those with mild cognitive impairment. This information could be used to reduce the incidence and early morbidity of neurodegenerative dementia.

Method

Participants

This study included 12 patients with amnesic MCI (aMCI) [12], individuals with SCI, and 12 NE. Patients with aMCI were diagnosed by a neurologist according to the following criteria proposed by Petersen et al. [16]: (1) memory complaint usually corroborated by an informant; (2) objective memory impairment for age; (3) essentially preserved general cognitive function; (4) largely intact functional activities; (5) not demented. Patients with aMCI underwent neuropsychological tests using the Seoul Neuropsychological Screening Battery [17].

Based on the definition of SCI in a previous study [18], the inclusion criteria were as follows: (1) self-reported cognitive decline and (2) essentially preserved general cognitive function. The patients in the NE group had no history of neurological or psychological disorders. The participants had adequate vision and hearing to perform the tasks.

All participants scored within the normal range on the Korean version of the Mini-Mental State Examination [19] and had no symptoms of depression on the Geriatric Depression Scale Short Form Korean Version [20].

The demographic characteristics of the patients with aMCI, SCI, and NE are summarized in Table 1. One-way ANOVA revealed no significant differences between the aMCI patients, SCI, and normal controls with regard to age ($F=0.221$, $p>0.05$), years of education ($F=0.149$, $p>0.05$). Informed consent was obtained from all participants, and the study was approved by the Institutional Review Board of Daegu University (IRB#: 1040621-202107-HR-013).

Materials and Procedure

Word definition task

We developed a word definition task composed of nine concrete nouns. Referring to previous studies, 119-word items were initially selected based on semantic categories [21], definition categories [22],

and imageability [12]. Among these words, homonyms and words whose meaning changes when used as nouns/verbs were excluded. In addition, based on the Korean vocabulary frequency dictionary, the word list was divided into high, medium, and low frequencies. Based on previous research results showing that the definition categories in which age-related or neurological deterioration in word definition ability appear are different, 33 words were defined for 10 normal adults (Mean age = 29.7 (\pm 2.16); Mean years of education =16). Only the words that yielded all four definition categories (perceptual, functional, relational, and categorical) were included. Nine words, three for each frequency, were selected as the final test words.

Pilot study

Prior to the field study, a pilot study was conducted by referring to the methods of previous studies [12,15] to determine the criteria for the definition score. In a previous study [15], the occurrence rate of each word's definition response was analyzed, and core and supplementary meanings were classified based on the content commonly produced by many people. In this study, after performing a word definition task on 40 NE people over 65 years old (Mean age = 69.5 years \pm 2.86, Mean level of education = 13.95 \pm 2.00), the occurrence rate of the definition response content of each word was analyzed to determine the frequency of occurrence. 'Two points' are given for core meanings with high frequency of occurrence, '1 point' is given for supplementary meanings with low frequency of occurrence, and 'content is ambiguous,' 'content is not related to the target word,' or 'content is not produced' were classified as '0 points,' and the primary scoring standard was selected. Examples of the final scoring criteria are listed in Table 2.

Scoring

Definition score: Each question was scored using 3 points (core meaning, supplementary meaning, and no response/irrelevant response). The number of semantic features (i.e., airplane: 'flying in the sky,' 'fast,' 'airport') calculated for each word was also considered and used to calculate the total score for each question. The range of points that could be assigned to the content derived from one word was limited to a maximum of 10 points. When calculating the total score, to distinguish between people who calculated at least one core meaning and those who calculated only several supplementary meanings, the score that could be given when only supplementary meanings were calculated without the core meaning was limited to a maximum of two points. When calculating the total score, the score was first filled with the number of core meanings; if 10 points were not met with only the core meaning, the score was filled with supplementary meanings.

Type of definition: The type of definition was broadly classified into perceptual, functional, relational, and categorical, and an error-type analysis was performed on responses that did not fall into these categories. (1) Functional definition refers to actor and instrumental functions; (2) perceptual definition refers to parts, materials, properties, and ideas; (3) relational definition refers to background, location, analogy/comparison/contrast, negation, principle, association, and abstraction; (4) categorical definition includes concepts such as specific hypernyms, general hypernyms, hyponyms, and synonyms.

Error type: In this study, the error types were organized by clustering similar errors in responses that received '0 points (no response/irrelevant response)' among the definition responses and

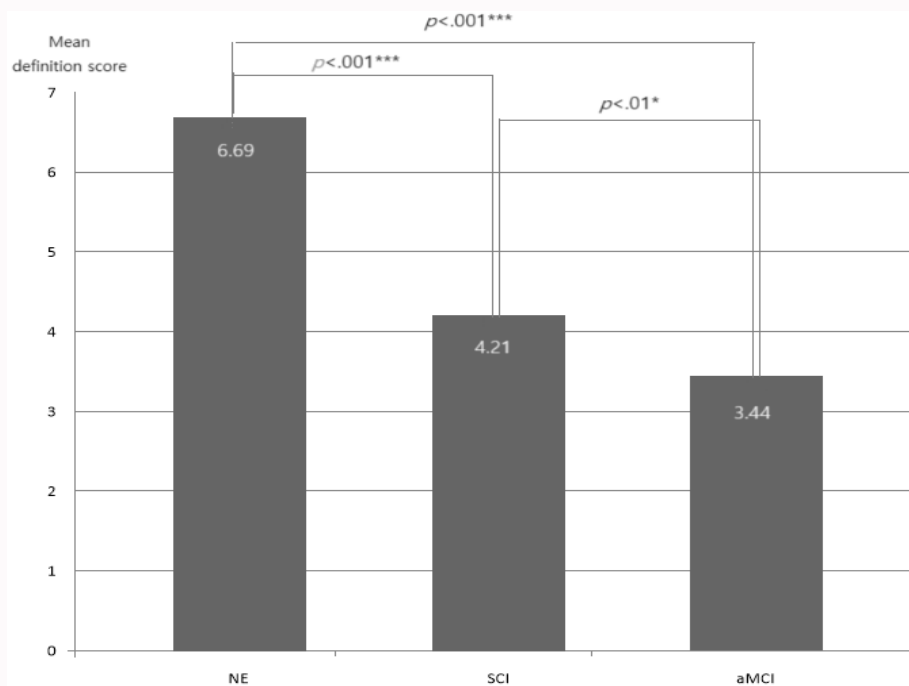


Figure 1: Bonferroni post hoc results on the difference in mean definition scores between the three groups.

Table 1: Demographic features of normal elderly, subjective cognitive impairment, and mild cognitive impairment.

| | NE (N=12) | SCI (N=12) | aMCI (N=12) | F |
|--------------------|--------------|--------------|--------------|-------|
| Age | 69.10 (2.10) | 69.90 (1.80) | 70.42 (1.17) | 0.221 |
| Years of education | 14.20 (1.99) | 14.00 (2.02) | 14.34 (2.17) | 0.149 |

Mean (Standard Deviation); ***p<0.001; **p<0.01; *p<0.05

Table 2: An example of the final scoring criteria.

| Definition score | Air plane |
|------------------|---|
| 2 points | Fly/go (in the sky, in the air); (to carry many people/many luggage); |
| | Go around; carry goods; Fast/time-saving; high; There is an engine; |
| | Long distance/able to go far; When going (overseas/across the water/travel/Jeju Island); Means of transportation etc. |
| 1 point | Takes off; machine/aircraft; thing; airstrip; Airport/Domestic/International; airplane; in-flight meal; not impart; comfortable; convenient; Dangerous; heavy; Passenger plane/fighter/helicopter/drone; Traveler/Pilot/Co-Pilot/Stewardess/Cook etc. |
| 0 points | I don't know, no response |

then analyzed based on the error type analysis table (Table 3). Error types were classified as 'insufficient definition', 'use of gestures', 'reaction to personal experience', 'repetition', 'use of substitute words', and 'do not know'.

Field study

To ensure that the participants understood the word definition task, practice questions were administered, and then the word definition task was performed. The researcher asked the participant "Please explain the target words?" or "What is OO?" If there was little or no response, the response was stimulated by asking "Can you tell me everything that comes to mind about OO?" [23,24] When prompting a response, if there was no defined response for more than 30 s, the participant moved on to the next question.

Statistical analyses

This study used the statistical analysis program, PASW SPSS (version 25.0). First, a two-way ANOVA was performed to examine the difference in definition scores according to word frequency (high, mid, and low) among the three groups, and a Bonferroni post-hoc

analysis was performed to determine whether there was a significant difference. Second, an X²-test was conducted to examine whether there was a difference in the frequency of prevalence of type of definition among the three groups. Third, a frequency analysis was conducted for each error type and presented as a percentage to compare the occurrence rates of the error types among the three groups.

Results

Examining the differences in mean definition scores according to word frequency among the three groups (Table 4) revealed a main effect of group on mean definition scores (F=68.765, p<0.001) (Table 5). The Bonferroni post-hoc test (Figure 1) showed that the mean definition score was significantly higher in the NE group than in the SMI and aMCI groups and in the SMI group than in the aMCI group. From the x²-test for the difference in frequency of prevalence of definition types among the three groups (Figure 2), a significant difference was found (X²=92.446, p<0.001). The prevalence of error types observed during word definition also differed among the three groups. The NE group mainly showed 'insufficient definitions,'

Table 3: Error type analysis table.

| | Description | Example |
|-------------------------|---|--|
| Insufficient definition | It is related to the target word, but does not correspond to the core meaning or supplementary meaning, or the content is insufficient. | Air Conditioner: "Be careful of air conditioners. Otherwise, the stomachache will last for a long time." |
| Personal response | Describes personal experiences or thoughts about the target word | Bicycle: "I can't ride a bicycle." |
| Repetition | Repeating content similar to the target word several times | Map: "Map, map, that map" |
| Gesture | Expressing the target word by pointing, hand gestures, or gestures without explaining it. | Tambourine: (waving hand) "This is what we do." |
| Use of substitute words | Speaking without gestures and using substitute words (i.e., this, that, these..) | Toothbrush: "You know what you do with your teeth like this? that" |
| Don't know | No response and don't know | Map: "Well, I'm not sure." |

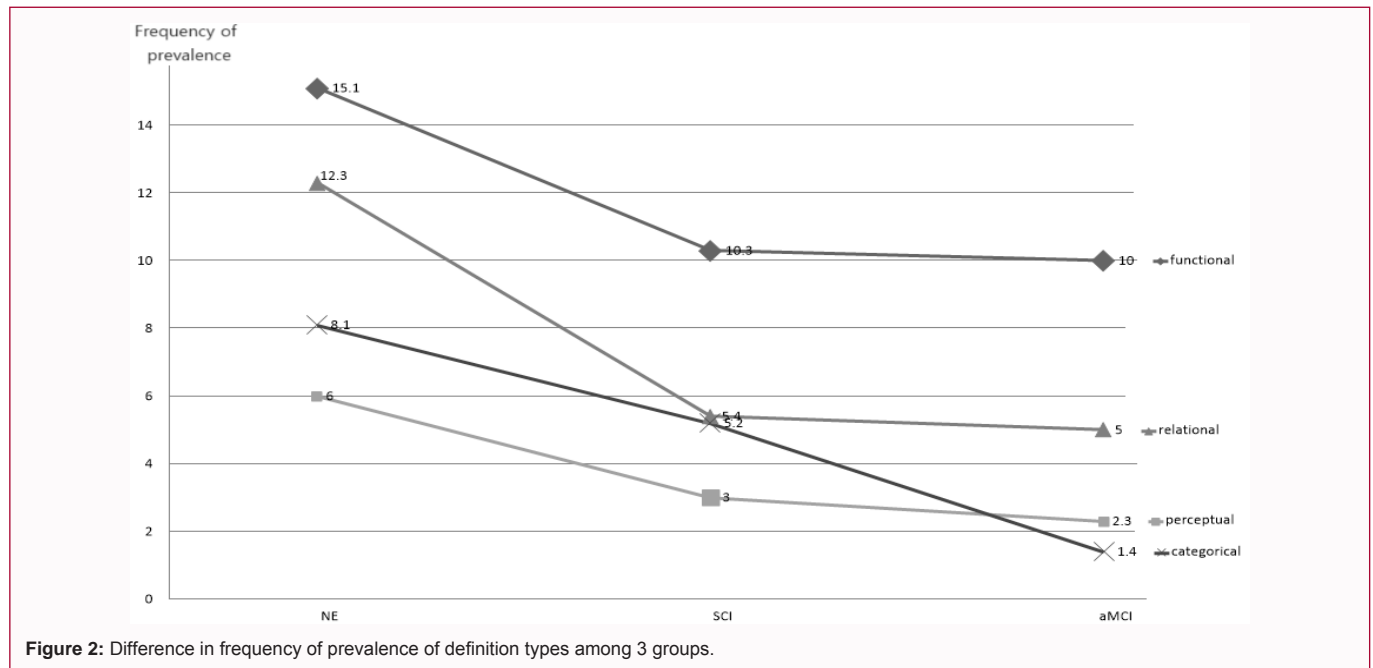


Figure 2: Difference in frequency of prevalence of definition types among 3 groups.

whereas the SCI group showed the 'repetition' error pattern of saying what was said several times, and the aMCI group showed the 'personal response' error pattern of saying personal thoughts or experiences about the target word (Table 6).

Discussion

SCI may be a clinically meaningful indicator of future cognitive decline, with individuals experiencing subjective memory complaints at increased risk of developing MCI and dementia [25]. One of the difficulties experienced by people who appeal subjective memory problems is that 'they cannot quickly come up with names.' Poor performance in the naming task is associated with changes in the cognitive and linguistic abilities that occur during aging [26]. Therefore, recently, as a new way to approach the initial mechanism of semantic knowledge damage, word definition tasks have been actively applied to investigate the form and strength of connections between concepts in a semantic network.

In this study, we conducted a word definition task for NE, SCI, and aMCI and analyzed their performance quantitatively and qualitatively in a multi-dimensional scoring system, thereby showing significant differences in the use and access ability of semantic knowledge. Even if individuals with SCI obtained normal results in objective neuropsychological tests, weak connections in the semantic network were discovered because of a detailed analysis of the number and pattern of use of semantic features and pattern of use of definition

Table 4: Descriptive statistics of mean definition scores according to word frequency among the three groups.

| Group | NE | SCI | aMCI |
|------------------|-------------|-------------|-------------|
| Frequency | (N=12) | (N=12) | (N=12) |
| High | 6.44 (1.85) | 4.54 (1.93) | 2.76 (1.91) |
| Mid | 6.80 (2.16) | 4.16 (2.08) | 3.91 (1.69) |
| Low | 6.82 (2.33) | 3.92 (1.64) | 3.66 (1.62) |

Mean (Standard Deviation)

Table 5: Two-way ANOVA results on the difference in definition scores according to word frequency between the three groups.

| | SS | DF | MS | F |
|----------------------|---------|-----|---------|-----------|
| Group | 514.941 | 2 | 257.471 | 68.765*** |
| Word frequency | 6.897 | 2 | 3.448 | 0.921 |
| Group*word frequency | 24.138 | 4 | 6.037 | 1.612 |
| SE | 977.234 | 261 | 3.744 | |

***p<0.001; **p<0.01; *p<0.05

categories. We consider the following three aspects.

First, the mean definition scores decreased significantly in the order of NE (M=6.69), SCI (M=4.21), and aMCI (M=3.44). In addition to the quantitative score-reduction effect, the types of defined meanings (core/supplementary meanings) also varied qualitatively.

While the NE group produced only the core meaning to achieve the highest definition score of 10 for each question, the SCI group

Table 6: Comparison of occurrence rates of error types between three groups.

| Group Error types | NE (N=12) | SCI (N=12) | aMCI (N=12) |
|-------------------------|--------------|---------------|----------------|
| Insufficient definition | 70% | 26.66% | 11.90% |
| Personal response | 20% | 6.67% | 41.67% |
| Repetition | 5% | 36.67% | 17.86% |
| Gesture | - | 13.33% | 14.29% |
| Use of substitute words | - | 10% | 9.52% |
| Don't know | 5% | 6.67% | 4.76% |

reduced the number of core meanings produced, secured some points for supplementary meanings, or had a definition score of '0'. This pattern was further intensified in the aMCI group, and the definition task was performed by calculating only supplementary meanings; questions with no response or 'do not know' responses were frequently reported.

Defining a word requires the ability to find the word to be defined in the mental lexicon, select other meanings related to the word within the semantic network, and find related information by identifying relationships with other related words [27]. Therefore, the results of this study are consistent with previous research showing that the connectivity of areas related to semantic memory is reduced in patients with SCI who experience anatomical changes in the frontal gyrus [28].

Second, the calculation frequency of the definition types tended to gradually decrease in the order of NE, SCI, and aMCI; however, the prevalence rate of each type among all the calculated definition types showed different patterns for each group. Elderly individuals with memory problems or dementia rely on functional semantic knowledge when defining nouns [29]. In this study, compared to other definition types, the frequency of prevalence of the functional definition category was observed to fall most gently as it progressed from the NE to the SCI and aMCI groups. However, semantic knowledge about the concept of the higher category to which a word belongs or perceptual features may be lost at an earlier stage [9,30]. In this study, the frequency of prevalence of categorical and relational definition types showed a rapid decrease, starting with the SCI group. This implies that the low performance of individuals with SCI in using mental flexibility, semantic categorization, and memory strategy also affects word definition, which may indicate the hallmark of SCI [31].

Third, analyzing error patterns demonstrated that compared to the NE group, the ability to access and quickly retrieve other words or meanings related to the target word showed a distinctive change in the SCI group. This aspect can be because the use of gestures and substitutes, which were not observed in the NE group, increased significantly in the SCI group.

Semantically spreading integration occurs in prefrontal regions, which may be vulnerable to MCI. Consequently, only a partial specification of word meanings can be achieved, producing fewer definitions. Previous studies examining the ability to define words have confirmed that patients with MCI show significantly lower performance than normal older adults [15,32]. Semantic deficits of aMCI can sometimes be difficult to notice because of their mild nature [15], and through quantitative and qualitative analyses of performance on the word definition task, distinctive characteristics of each group were identified.

As the definition that SCI must be normal on neuropsychological

tests is included in the diagnostic criteria, there is a mutually contradictory aspect as to whether observing deteriorated abilities in actual cognitive-linguistic tasks is clinically useful. Nevertheless, the significance of this study is that it confirmed that SCI, unlike NE, has deteriorated semantic processing knowledge and that discriminatory differences were observed in the stages progressing to NE, SCI, and aMCI. The difference is mainly because they employed different scoring methods. While the previous study used a 3-point equal-interval scoring method (i.e., 0, 1, and 2 points), we adopted total scores (sum of core and supplementary meanings), which may be more multidimensional and therefore more sensitive to subtle pathological group differences.

Conclusion

This study was conducted under the assumption that a decline in the processing ability to quickly search for and select relevant information and inhibit unnecessary information owing to the decline/deterioration of frontal lobe executive function could be detected through sensitive linguistic tasks for detecting semantic deficits. If the results obtained in this study are used for the early diagnosis and follow-up of SCI, the impact of related neurodegenerative disorders leading to MCI and AD can be alleviated.

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