Emotion and Reading Comprehension in Elderly and Young Adults: An ERP Study

Hyunji Kim, Youngsun Jin*

ABSTRACT

The purpose of this study is to determine the effects of emotion and information processing methods on the reading comprehension of elderly and young adults by measuring event related potentials (ERPs). Thirteen young men and thirteen elderly people participated in this study. The elderly subjects were selected using the Korean-Mini Mental State Examination (K-MMSE). We used the N400 event-related potential component to measure the ease of processing implausible words. The results of this study showed that young adults had higher accuracy and faster response times for sentence discrimination than elderly adults. The results showed that older adults had higher N400 amplitudes in the negative than positive emotion condition, whereas younger adults showed no influence of emotion. The results demonstrated that adopting an algorithmic reading method to read word-by-word in elderly people reduces the cognitive burden. This finding suggests that young and older adults' optimal reading performance may differ in positive and negative emotional states.

Key Words: Emotion, Aging, Reading, N400, Information processing

DOI Number: 10.14704/nq.2019.17.01.1902 **NeuroQuantology 2019; 17(01):50-58**

Introduction

It is well known that emotions have a great influence on human cognitive activities. For example, if one is in a good mood, taking a walk can be enjoyable, but walking while in a depressed mood may be unpleasant. In other words, the same action of walking can be perceived differently depending on our mood or emotional state. In addition to altering the situation, emotions can affect cognitive activities, problem solving and reasoning, and even reading skills essential for everyday life (Bohn-Gettler and Rapp, 2011; Egidi and Gerrig, 2009; Egidi and Nusbaum, 2012; Havas et al., 2007). As people read text, they go through a series of complex processes, such as perceiving, analyzing, reasoning, and understanding the core of the words (Morrow and Bower, 1990; Just and Carpenter, 1987). Emotions also affect such cognitive processes related to reading.

In addition, emotions affect one's heuristics and algorithmic information processing during reading. Therefore, in order to study reading comprehension for elderly individuals who are not sensitive to emotions, it may be necessary to consider heuristic and algorithmic information processing methods. According to Clore and Huntsinger, (2007), positive emotions promote the use of heuristics and negative emotions facilitate algorithmic processing. The use of heuristic methods deduces new information based on the content of the article being read so that the contents to be presented later can be more easily predicted. On the other hand, it is difficult to deduce the content of subsequent readings because reading in algorithmic methods emphasizes individual pieces of information rather than information flow or context (Schwarz, 2002). For example, Hannon and Daneman (2009), argue that elderly people are less

Corresponding author: Youngsun Jin
Address: Department of Psychology, Kyungpook National University, Republic of Korea
e-mail ysjin@knu.ac.kr

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 09 October 2018**; Accepted:** 23 December 2018

capable of reading than young people because they lack the ability to combine old information with new when reading. However, it is somewhat unreasonable to conclude that the reading ability of elderly people is lower than that of the young people simply because of the information processing method. Therefore, it is necessary to study the influence of the dependence on heuristic and algorithmic processing during reading in young and elderly people.

To date, there is no direct comparative study of the effects of information processing methods on reading comprehension for elderly and young people. However, a neurophysiological study using the N400 showed that elderly people are more dependent on algorithmic information processing than heuristic information processing methods (Wlotko et al., 2012). Wlotko *et al*., (2012) investigated differences in reading comprehension between elderly and young people using sentences containing weakly constraining words and sentences containing strongly constraining words. They found that there was no difference in the amplitude of the N400 between the elderly and young people in the difficult word condition, but the N400 amplitude in the young people was smaller than that in the elderly people in the sentence in which the word was easily predicted. Although predictable followed, the elderly showed a lesser neurological response to the expected sentence because of the poor connection between the previous context and the word. This study not only directly proves that the inferior reasoning ability of the elderly is due to the degradation of heuristic use, but also shows that the information processing methods of young and old people are different.

Several researchers investigated the effects of negative and positive emotions on reading using the N400. Chwilla *et al*., (2011) briefly showed emotion-inducing images to participant and then presented a final word with a high-cloze sentence that is easy to predict (e.g., in the library, pupils borrow books) and a difficult-to-predict low-cloze sentence (e.g., the pillow is filled with books). The results showed that the amplitude of the N400 in the positive emotion condition was large in both conditions and the amplitude of the N400 was small in the negative emotional state. This suggests that positive emotional states are more likely to a cause neurological response to the emergence of low-cloze words and that neurological responses are relatively minor even in the presence of difficult-to-predict words in negative emotional states. In addition, Van Berkum *et al*., (2013) also revealed that emotions can affect reading comprehension through the N400. They used a causality-bias sentence that requires explanation of cause and effect, such as who is praising or apologizing to whom. For example, the amplitude of the N400 was larger in the positive emotional state than in the negative emotional state when the unexpected B was inserted in place of A in the blank. in "A apologized to B because --- dropped B's bowl". This indicates that the appearance of unexpected words in a positive emotional state results in a larger N400.

A comprehensive review of the literature on the relationship between emotions and reading showed that positive emotions increase the efficiency of reading, while negative emotions decrease efficiency. However, since most previous studies have been performed using young adults who are estimated to have relatively good reading ability, it is questionable whether they can be generalized to older people who are expected to suffer from cognitive decline. Therefore, the purpose of this study is to determine the effects of emotion and information processing methods on the reading comprehension of elderly and young adults by measuring event related potentials (ERPs). It is expected that elderly people who are dependent on algorithmic information processing would be disturbed by heuristics in a positive emotional state, and the amplitude of the N400 would appear to be relatively low for the infringing word. On the other hand, in the negative emotion condition, the cognitive resources invested in each word are increased because the elderly people's algorithmic processing is facilitated. It is hypothesized that the amplitude of the N400 would be larger for the inappropriate word.

Methods

Participants

Thirteen young men (M = 23.23, SD = 1.58) and thirteen elderly people (M = 69, SD = 6.01) participated in this study. There was no difference in the educational level of the participants. The elderly subjects were selected using the Korean-Mini Mental State Examination (K-MMSE). Their average score was 25 points or more and there was no abnormality in the function of cognitive abilities. All participants provided informed consent before the experiment and were given instructions on the experimental procedure. All participants were right-handed, and there was no neurological or visual problems. After

the completion of the experiment, a fee of 20 dollar was given to participants.

Apparatus and stimuli

Korean-Mini Mental State Examination (K-MMSE): The MMSE is a tool for the simple and rapid measurement of cognitive impairment. It is used primarily in elderly people or patients who are concerned about dementia symptoms. The MMSE was first developed by Folstein *et al*. (1975) to evaluate the mental state of elderly people, and was translated to Korean (K-MMSE) by Kang et al. (1997). The Cronbach's α of the K-MMSE is 0.86. The K-MMSE comprises questions about orienting in time (5 points), orienting in location (5 points), memory registration (3 points), memory recall (3 points), attention and calculation (5 points), execution ability (3 points), language ability (3 points), time and space composition ability (1 point), and judgement and comprehension ability (2 points) (19 items with a total of 30 points).

Korean Positive Affect and Negative Affect Schedule (K-PANAS): The PANAS was first developed by Watson *et al*. (1988) to measure current emotional state, and it was translated to Korean version by Lee *et al*. (2003). The Cronbach's α of the K-PANAS is 0.86. K-PANAS is composed of 10 words (active, suspicious, fearful, etc.), all adjectives representing positive and negative emotions. The K-PANAS was rated on 5-point Likert scale.

Sentence: In this study, we used a total of 200 Korean sentences consisting of "subject (complement) - adverb - object - (modifier) - predicate" constituents as stimuli, for example, "I ate lunch with a friend." Approximately 300 sentences considered emotionally neutral were extracted from a general novel or non-fiction book. The emotional valence of 300 sentences was assessed by 26 subjects who did not participate in the experiment. They rated the 300 sentences using a 7-point Likert scale (1 = very negative; 7 = very positive); 200 sentences close to 4 points (considered neutral in emotion) were extracted (M = 4.62, SD = 0.265 range = 3.35–4.69). Among the 200 selected neutral sentences, the last word of the predicate of the 100 sentences was substituted to its antonym. It was manipulated to be incompatible with the rest of constituents and made into an implausible sentence (e.g., Rain rose all day today, I swallowed lunch with a friend today). In order to confirm that the sentence was unpredictable, prediction tests with 25 subjects who did not participate in the experiment were conducted and no subjects were able to predict the last sentences.

Video: In this study, moving images such as those from a documentary or variety show were edited and used as emotion-inducting stimuli. Participants watched images for 5 to 6 minutes of positive and negative emotional conditions. The positive images consisted of children and their families playing together, youngsters enjoying family entertainment, and Korean citizens crying during the 2002 World Cup because the Korean team were victorious. Negative images consisted of images of patients suffering after surgery, the sinking of a ship, and the death of a pet dog. The emotional valences of the videos as rated by the 26 subjects were 6 (SD = 0.20) for the positive images, 3.88 (SD = 0.187) for the neutral images and 1.74 (SD = 0.182) for the negative images, on a scale ranging from 1 to 9 (negative to positive) ($P < 0.001$).

Procedures

Upon arriving at the laboratory, written informed consent was obtained from each participant and elderly participants underwent the K-MMSE. When participants were ready to undergo ERP measurement, they entered the noise- and lightproof chamber and were instructed to refrain from blinking and body movements during the experiment. After preparations were completed, we showed a positive or negative emotion-inducing image to the participants using a 27 inch" LCD screen. The K-PANAS was performed immediately before and after viewing the images to confirm that the intended emotion was well induced. After this procedure, 100 sentences were presented to participants using a rapid serial visual presentation (RSVP) method where words are presented quickly, one-by-one. The fixation time before the start of the sentence was 1000 ms, the presentation time of each word was 200 ms, and the inter-stimulus interval (ISI) was 300 ms, referring to the paper by Federmeier and Kutas (2005). After presenting the last word, we presented a blank screen for 800 ms until participants judged the validity of the sentence. After the blank screen was over, they have to judge the correctness of the sentence within 2000 ms. The judgment of whether the sentence was correct or not was signaled using the '/' and 'Z' keys of the keyboard, which were counterbalanced. After the sentence validity judgment was completed, we conducted the PANAS again to confirm that the emotion was well maintained. At the end of this process, the participants took a break for about 5 minutes. After resting, the above process was repeated with the rest of the emotion-inducing images. The experiment took about 50 minutes.

Data processing and analysis

BIOPAC (Biopac Systems, Santa Barbara, CA) was used to correct ERP data from P4, PZ, P3, C4, CZ, C3 using the international 10–20 EEG electrode placement system (Jasper, 1958). The sampling rate was 512 Hz and the impedance values were maintained below 5 kΩ at all sites. A reference electrode was attached to the right earlobe and left and right mastoid served as the ground. Eye movements were monitored with electrodes attached below and above the right eye using electrooculography (EOG). To remove noise, a 0.05–32 Hz band pass filter was deployed with a 24 dB/octave roll-off, and a 60 Hz notch filter was applied. The EOG artifact was removed using an independent component analysis-based method. A finite impulse response (FIR) low-pass filter was applied to the EEG with a frequency range from 0.001–14 Hz. Baseline correction was performed by averaging the signal from -200 ms to 0 ms before the start of stimulus presentation and subtracted from the rest of the data. Amplitude of more than 200 μv or less than -200 μv were excluded in the analysis. Data were analyzed using MATLAB2010.

The accuracy and response time for judging sentence validity were measured after emotion induction. We analyzed the accuracy for all sentences, combining the valid and unreasonable sentences. A 2 (age) × 2 (emotion) mixed design was applied to analyze response time and accuracy. The emotion induction was analyzed with a 2 (groups) × 2 (emotion) × 3 (time) ANOVA with repeated measures for the last two factors. The dependent variable was the K-PANAS score.

The ERP was only analyzed for the wrong predicate of implausible sentences. The dependent measure is the N400 amplitude for the wrong predicate and the ERP analysis measured the highest amplitude and at a latency of between 300 and 500 ms from the appearance of the wrong predicate. A 2 (group) × 2 (emotion) × 6 (area) ANOVA with repeated measures for the last two factors was performed on the ERP data. The Greenhouse and Geisser (1959) procedure was used to compensate for possible violations of the sphericity assumption. The original degrees of freedom and corrected probability level are reported.

Results

Positive emotion induction

Both groups had significantly higher scores than baseline for positive items just after positive images had been presented (all $p < .05$) (Fig. 1). This showed that positive emotions were successfully induced, and there was no difference in the response to positive items until the end of the task (young $p = 0.421$, elderly $p = 0.179$). On the other hand, there was a difference between the two groups regarding the negative items after being presented positive images. The elderly showed a lower score than baseline in response to negative items after positive images (all $p < 0.05$). The negative emotions decreased immediately after the video and were maintained well until the end of the task ($p = 0.613$). On the other hand, negative emotional responses to positive images showed no significant difference between baseline, immediately after video, and immediately after task (baseline and after video, $p = 0.775$; after video and after task, $p = 0.659$). However, it can be seen that the process of inducing positive emotions in young people was successful ($p < 0.001$), because the responses in young people to positive items were significantly higher than those to negative ones.

Negative emotion induction

Both groups showed a lower score than baseline for items that were evaluated affirmatively immediately after negative image presentation (all $p < 0.001$) and maintained a low positive emotional response until the end of the task (young, $p = 1.00$; elderly, $p = 0.535$). Likewise, in the item evaluating the negative response, both groups showed higher scores than baseline, and there was no difference in the negative response from immediately after the image presentation until the end of the task ($p = 0.369$; $p = 0.486$). This shows that both groups successfully induced emotions (Fig. 1).

Behavioral data

Response time: Analysis of sentence validity showed a significant main effect for group [$F(1, 50) = 98.221$, $p < 0.01$]. The response time of the elderly (697 ms, SD = 140 ms) was longer than that of the young people (399 ms, SD = 125 ms). However, there was no main effect for emotion [$F(1, 50) = 0.043$, $p = 0.837$] or group × emotion interaction [$F(1, 50) = 0.163$, $p = 0.688$].

Accuracy: Analysis showed that the accuracy of the elderly group (0.815 %, SD = 0.14) was significantly lower than that of the young group (0.91 %, SD = 0.09) [$F(1, 50) = 9.217$, $p = 0.004$]. No other significant main effect for emotion [$F(1, 50) = 2.969$, $p = 0.091$] or interaction between group and emotion were found [$F(1, 50) = 0.940$, $p = 0.337$].

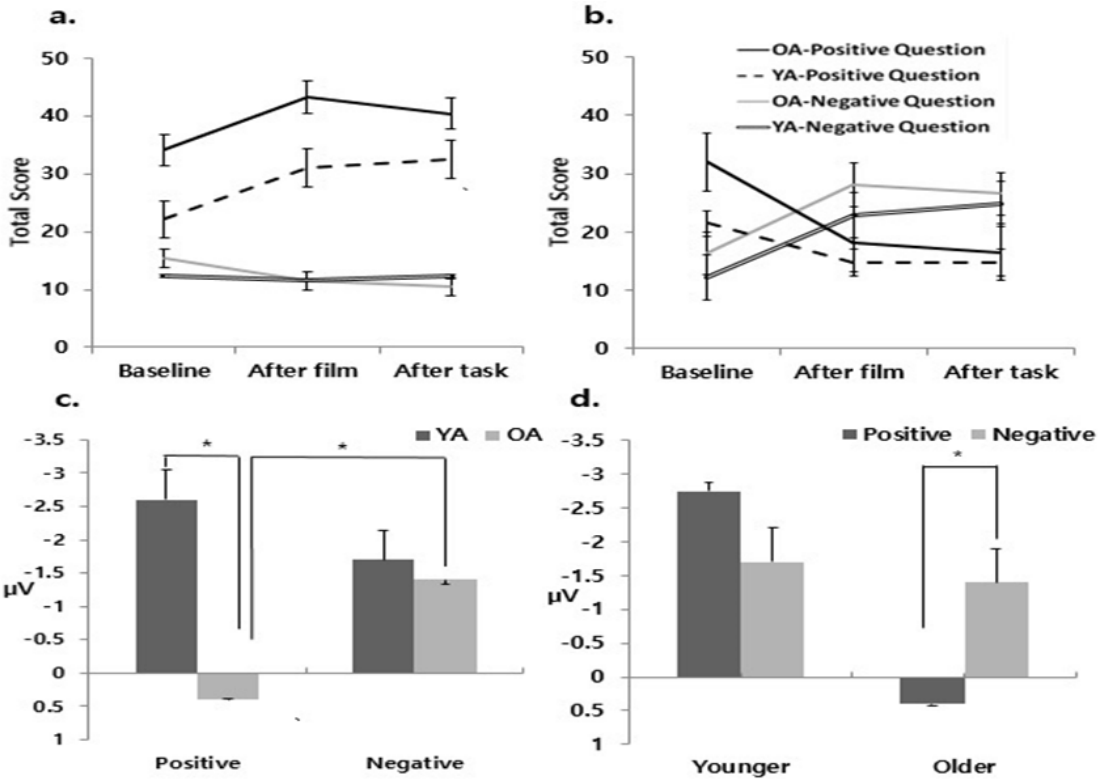

Figure 1. (a) Total score after positive mood induction in younger and older adults. (b) Total score after negative mood induction. (c) Differences of peak in young and old adults in each mood induction process. (d) Differences of peak in each mood induction in younger and older adults

ERP Amplitude: Analysis of the amplitude in response to wrong words revealed no significant effect of group [F (1, 24) = 3.005, p > 0.96] or emotion [F (1, 24) = 0.351, p > 0.559]. However, there was a significant main effect of area [F (2.283, 54.790) = 5.007, p < 0.05]. Post-hoc testing indicated that the N400 amplitude at C4 was higher than that at P4 (p = 0.013) (Fig. 2). In addition, a group by emotion interaction was found [F (1, 50.931) = 4.974, p < 0.039]. Post-hoc testing showed that young people did not show any difference in N400 amplitude between positive and negative conditions, but older people had smaller N400 amplitude for positive emotions than negative emotions (p < 0.001). Group × area [F (2.283, 50.931) = 1.283, p > 0.05], emotion × area [F (2.122, 50.931) = 1.341, p > 0.05, and group × emotion × area [F (2.122, 000) = 1.224, p > 0.05] were all non-significant.

Latency: Analysis of the latency in response to wrong words revealed no significant main effect for group, emotion, or area. However, the interaction between group and emotion [F (1, 66.893) = 9.785, p < 0.005] and the group × emotion × area interaction [F (2.7871, 66.893) = 2.791, p < 0.05] were significant. One-way ANOVA showed that there was no difference in the latency between the young and elderly people in the positive emotion condition [F (1, 24) = 1.754, p = 0.198]; however, the latency in elderly people at C3, Cz, and C4 was greater than that in the young people in the negative emotion condition [F (1, 24) = 5.141, p = 0.033] (Fig. 2) There was no significant effect of group [F (1, 24) = 0.426, p > 0.05], emotion [F (1, 24) = 0.674, p > 0.05], or area [F (1.883, 45.196) = 0.179, p > 0.05], or group × area [F (1.883, 66.893 = 0.284, p > 0.05] or emotion × area [F (2.787, 66.893) = 0.642, p > 0.05] interaction.

Discussion

The purpose of this study was to determine the psychophysical effects of reading on the emotions of elderly and young adults using the N400. The results of this study showed that young adults had higher accuracy and faster response time for sentence discrimination than elderly adults. These results indicate that elderly people have worse reading comprehension than young adults. Caplan *et al.* (2011)'s findings support the results of this study, reporting that elderly people have lower cognitive abilities to help memory and language processing as they get older and have a worse understanding of sentences than young adults. On the other hand, Hannon and Daneman (2009) explained that the lower reading comprehension of the elderly is

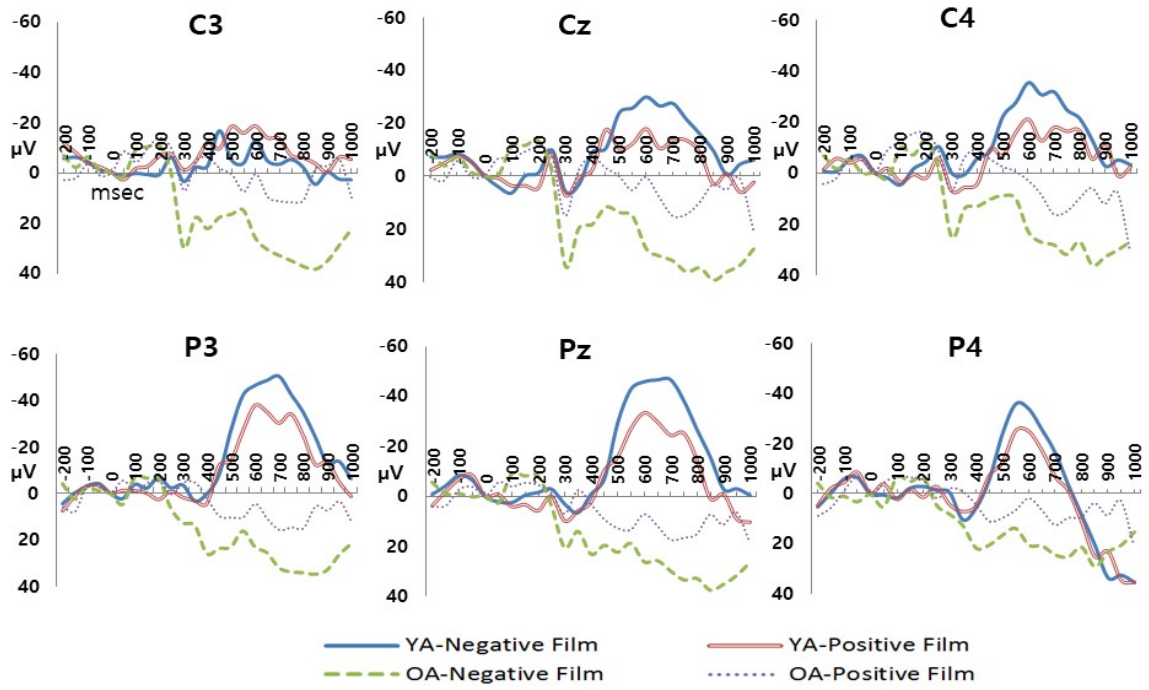

Figure 2. Grand average of the N400 between young adults (YA) and elderly (OA) after inducing positive and negative emotions in each area. The N400 amplitude of elderly people is larger than that of young people for all channels. The elderly participants have a high N400 amplitude in the negative emotion condition, and young people have a high N400 amplitude in the positive emotion condition

due to the fact that the working memory capacity consumption is bigger than in young people for the process of combining new and existing information. However, it is somewhat unreasonable to directly compare the results of this study to previous research concerning the accuracy and response time of sentence discrimination. This is because the time between when the subject is presented the wrong predicate and when the sentence is judged is 800 ms, and the behavioral response may have already been made regarding the judgment of whether the sentence is right or wrong.

According to Verhees *et al.*, (2015), the response time of subjects judging the validity of sentences is less than 800 ms. In other words, the accuracy and response time in this study are not measurements of the sentence judgment response, but may instead reflect the response time of the elderly and young adults. In the present study, there was no difference in the sentence judgment accuracy between emotional conditions. This result seems to be due to the rapid visual stimulus presentation method used in this study. The presentation of RSVP stimuli increases the consumption of attention resources and offsets the effects of pre-induced emotions. De Martino *et al.*, (2008) support this interpretation by claiming that the RSVP method can invalidate the effects of emotion.

Analysis of the N400 amplitude showed that emotions had different effects on the reading of the elderly and young adults. Young adults showed a tendency to have higher N400 amplitudes in the positive emotion condition than in the negative emotion condition, but there was no significant difference between the two emotional conditions as expected. This means that young people were equally affected by positive and negative emotions when reading. This is different from previous studies (Van Herten et al., 2005) that suggested that positive emotions facilitate reading and negative emotions interfere with reading. As in this study, emotions have little impact on reading in young people because they have more cognitive resources than elderly people. Although negative emotions reduce attentional capacity in the prefrontal area and interfere with the performance of a task (Bishop, 2009), a study by Scheibe and Blanchard-Fields (2009), support this study's findings asserting that the working memory capacity of young people is more abundant than that of elderly people; thus, reading is not significantly affected by negative emotions.

On the other hand, elderly people showed a larger N400 amplitude for words that were semantically violated when they were in the negative emotion condition than in the positive emotion

condition as expected. This assumes that the elderly pay attention to each word using algorithmic information processing in the negative emotion condition, so that the N400 amplitude is large in response to the wrong word. The results of this study are consistent with the findings of Holt *et al*., (2009) who found that the amplitude of N400 increases when resource investment increases for words. Thus, the results of this study do not support Wang *et al*., (2016)'s claims that the negative emotional-algorithmic method interferes with reading. In this study, the elderly participants may have adopted a negative emotion-algorithmic method because this method is likely to be more efficient and comfortable when reading the text presented as in this study. This may be because understanding the text literally, rather than deducing new contents and combining with existing information, may reduce the working memory capacity requirement for elderly participants, especially considering that elderly people have less working memory capacity than young people. Therefore, adopting an algorithmic reading method to read word-by-word in elderly people reduces the cognitive burden. Whitney *et al*., (1991) support our interpretation by asserting that inferences of detailed information (e.g., each word) have lesser working memory requirements than making receptive inferences about the overall content of the text when reading. Therefore, the results of this study suggest that negative emotions facilitate reading comprehension in elderly participants, and positive emotions negatively affect reading comprehension because they need to use more cognitive resources.

Analysis of the N400 latency revealed that the latency was shorter in the elderly when reading during the positive emotion condition and longer in the negative emotion condition. In contrast to elderly people, young adults had a longer latency from positive emotions and shorter latencies from negative emotions. The latency of the N400 is known to be closely related to RSVP, age, working memory, and language proficiency (Ardal *et al*., 1990; D'Arcy *et al*., 2005). The long latency in elderly people is assumed to be due to the fact that negative emotions increased the burden on information processing when judging and reading sentences. Previous studies have reported that increased attention or increased memory load may increase the N400 latency (D'Arcy *et al*., 2005). D'Arcy *et al*., (2005) found a 50-ms delay (N450) in the N400 when the working memory load was increased in a task involving reading and memorizing the sentence, supporting the interpretation of our study. In addition, another reason for the long N400 latency is that negative emotions negatively affect the search for words when elderly people are reading. Ardal *et al*., (1990) and Maess *et al*., (2006) also claimed that the N400 latency was related to words and word search in sentences. The results of this study disagree with Mather and Carstensen (2005) who argue that elderly people are disturbed by subsequent tasks because they invest a lot of attention to positive emotion-inducing stimuli.

On the other hand, the young people had a shorter N400 latency after negative emotion induction. This may indicate that negative emotions in young people played a role as a reinforcer, not interfering with reading but rather improving concentration on the presented sentences, thus the latency is short with fast information processing. Bless and Fiedler (2006) support this interpretation having asserted that negative emotions raise motivation levels. It is also believed that negative emotions reinforce memory accuracy and that young people have a combination of existing information and the final word after negative emotion induction, resulting in a shorter N400 latency. In other words, it seems that young people are more efficient readers during negative emotional states than elderly people because they use information processing methods such as psychological resistance to properly separate attention. For example, if a noise or disturbance leads to negative emotions when reading, psychological resistance is developed to overcome the disturbance, thus increasing attention (Jeon *et al*., 2014) which may cause a shorter N400 latency.

Taken together, this study has revealed that different emotion al states have different effects on the reading comprehension of elderly and young adults. Previous research has demonstrated that positive emotions improve reading comprehension and negative emotions decrease reading comprehension. In the present study, it was found that young people were not affected by positive or negative emotional states, but the elderly participants improved their reading comprehension when they were in a negative emotional state. Elderly people with relatively low inferential abilities seem to compensate for poor reasoning abilities by giving individual attention to words. This suggests that elderly and young people may be differentially affected by the same emotional

stimuli when performing cognitive tasks such as reading. In later studies, it is necessary to study how decision-making and cognitive activities affect emotions depending on age.

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