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The Effect of an Enrichment Reading Program on the Cognitive Processes and Neural Structures of Children Having Reading Difficulties *

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Abstract

The main purpose of the current study is to explain the effect of an enrichment reading program on the cognitive processes and neural structures of children experiencing reading difficulties. The current study was carried out in line with a single-subject research method and the between-subjects multiple probe design belonging to this method. This research focuses on a group of eight students with reading difficulties. Within the context of the study, memory capacities, attention spans, reading-related activation and white matter pathways of the students were determined before and after the application of the enrichment reading program. This determination process was carried out in two stages. Neuro-imaging was performed in the first stage and in the second stage the students' cognitive processes and neural structures were investigated in terms of focusing attention and memory capacities by using the following tools: Stroop Test TBAG Form, Auditory Verbal Digit Span Test-Form B, Cancellation Test and Number Order Learning Test. The results obtained show that the enrichment reading program resulted in an improvement in the reading profiles of the students having reading difficulties in terms of their cognitive processes and neural structures.

Keywords: Cognitive process, Neural structure, Reading difficulties

Introduction

Research findings on the structure and function of the brain offer important insights for educators to understand concepts such as memory and attention (Bear, Connors & Paradiso, 2001; Gibb, 2007; McNeil, 2009). Though this research is of great importance for education, it cannot be argued that the link between brain research and pedagogy has yet been thoroughly constructed (Fischer, et al., 2007; Stemmer & Whitaker, 2008). When neuro-imaging research focusing on reading is examined, it is noted that the study groups

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generally consist of adults and that most such research has been conducted in the field of medicine (Aue, Lavelle & Cacioppo, 2009; Fletcher, et al., 2000; Rezaie, et al., 2011). As this research is not primarily aimed at educational applications, attempts to infer such from these studies can be misleading. It should be borne in mind that research conducted in the field of reading by means of neuro-imaging methods must adopt a neuro-cognitive and educational point of view. Additionally, one must be aware that data collected from children significantly differ from those collected from adults, and therefore study groups must comprise children, specifically, to be applicable to their education. The most fundamental feature of neuro-imaging research conducted on children is that it can yield development-based explanations. When the research conducted on reading in Turkey is examined, it is seen that there is hardly any study employing cognitive and neuro-cognitive approaches simultaneously to investigate reading. In the international literature, on the other hand, parallel to the development of neuro-imaging methods, investigation of reading difficulties in terms of cognitive processes and neural structure is emerging as a new field of study. Moreover, it can be maintained that it is of great importance to conduct research evaluating students' cognitive processes, cognitive structures and brain activation during reading. Investigation of the results of interdisciplinary studies clearly indicates the importance of neuro-imaging studies focusing on reading process and the need for further such studies.

Acquisition of reading skills actually starts when the baby is born. Experiences, and prior knowledge brought by students to the basic education process partially determine what kind of readers they will be. Some of the most influential elements of this process are the attitudes and behaviors developed by students towards reading skills, how their reading-related cognitive development is supported, what kinds of opportunities are provided for them and what kind of guidance they are offered. In short, what is important is to establish an enrichment learning environment suitable for the language acquisition and cognitive development of the child.

The current study is intended to provide guidance for the determination of cognitive processes and neural structures utilized by students having reading difficulties. Moreover, we believe enrichment reading programs developed on the basis of our findings will be useful to students dealing with reading difficulties, and to teachers, practitioners and researchers deciding how to integrate such programs into schools' general reading curriculums. The purpose of the current study is to explain the effect of an enrichment reading program on the cognitive processes and neural structures of students having reading difficulties.

Method

The current study was conducted using a single-subject research method and between-subjects multiple probe design.

Study Group

The study group for this research was composed of eight ten-year-old students having reading difficulties. The participants of the study were selected through the purposive sampling method. Two main criteria were employed in determining the study group: that students not have any visual or audio disorders and that their reading not be at the anxiety level. The following further criteria were additionally sought:

- That the student not have any affective or perceptive problems.
- That the student not have any neurological or developmental anomalies.
- That the student not suffer from claustrophobia.

- That the student not use any drugs affecting the neural system.
- That the student use their right hand.

Application of the Between-subjects Multiple Probe Design

The current study was carried out in line with the between-subjects multiple probe design. The experimental control in the study was set as a comparison of the participants' performance following the program with that demonstrated at the start of the study. By evaluating the performance of each student individually, students constructed their own control. The application process of the study included different stages, including beginning level, application sessions, monitoring sessions and post-instruction evaluation sessions. Within the context of the current study, the effect of the enrichment reading program on the cognitive processes and neural structures of more than one student in the same environment was investigated. It was ensured that the participants of the study would be independent of each other but have similar features.

Beginning Level. At the beginning level, the first stage, neuro-imaging was performed. At the second stage, data about the students' cognitive processes and neural structures in terms of their attention and memory capacities were collected by using the following tools: Stroop Test TBAG Form, Auditory Verbal Digit Span Test-Form B, Cancellation Test and Digit Span Learning Test.

Application Sessions. The enrichment reading program application sessions were composed of phoneme awareness, word recognition and identification, reading comprehension and fluent reading sessions.

Phoneme Awareness Application Sessions. In order to raise the phoneme awareness of the students, activities focusing on the recognized phoneme, disintegration of words into their morphemes, production of words with the given phoneme and division of words into their constituents were performed. The students were made aware of the fact that sentences are made up of words, words can be rhymed, words can start and end with the same phoneme, words can share the same syllables, words can be separated into their syllables, words can be disintegrated into their phoneme, new words can be constructed by discarding some phoneme from words and phonemes can be blended to make up new words. These phoneme awareness activities were carried out over five weeks.

Word Recognition and Identification Application Sessions. Word knowledge enables students to develop their word recognition and identification skills. Within these sessions, the students were provided with activities such as guessing the meanings of words from the context and clue instructions (for instance, teaching how to use synonyms and antonyms as clues). The word recognition and identification sessions sessions were carried out over four weeks and two days, taking ten hours of class time each week. Each lesson lasted nearly 40 minutes.

Reading Comprehension Application Sessions. Within these sessions, activities were conducted to determine the students' opinions about the text before, during and after reading and to instruct them in the following: how to set a goal for reading, how to use the information obtained from the text, how to make inferences from and judgments about the text, how to visualize the concepts related to the text and how to relate that information to their daily lives. These sessions lasted for four weeks.

Fluent Reading Application Sessions. The relationship between word recognition and comprehension is established through automation in word recognition, enabling the reader to focus on comprehension and prosodic reading that is conducted at a proper speed and expression. In order to develop fluent reading, activities including modeling, repeated reading, supported reading, peer reading, reader theater, oral reading, choir reading, shared reading, independent (individual) silent reading, reading friends, cyclical reading and trio-control reading were used. The fluent reading sessions lasted for two weeks.

Monitoring Sessions. Following each stage of the enrichment reading program, monitoring-based evaluations of reading performance were performed.

Post-Instruction Evaluation Sessions. At this stage, neuro-imaging was performed and data were collected about the students' cognitive processes and neural structures in terms of focusing attention and memory capacities by using the following tools: Stroop Test TBAG Form, Auditory Verbal Digit Span Test-Form B, Cancellation Test and Digit Span Learning Test.

Data Collection Method

Before and after the application, the participating students' memory capacities, attention spans and their state of activation related to reading were determined. This determination process was carried out in two stages. Neuro-imaging was performed in the first stage and in the second stage the students' cognitive processes and neural structures were investigated in terms of focusing attention and memory capacities by using the following tools: Stroop Test TBAG Form, Auditory Verbal Digit Span Test-Form B, Cancellation Test and Digit Span Learning Test.

The imaging of the neural structure was produced by using the task-based fMRI method. Functional data were collected by using Gradient Echo (GRE) and Echo Planar Imaging (EPI) sequences. The application of word recognition included six active (reading) tasks of 20 seconds each and six pause (black screen) tasks. Shooting parameters included TR/TE = 2000/35 ms, 3.4 mm isotropic voxel, 28 cross sections and 120 dynamic shootings. The text reading task application included five active (reading) tasks of 30 seconds each and five pause (black screen) tasks. Shooting parameters comprised TR/TE = 3000/35 ms, 3.4 mm isotropic voxel and 100 dynamic shootings. For T1-weighted structural anatomic shooting, TR/TE = 2600/3.02 ms, matrix = 224x256 and cross section thickness of 1 mm were used. Diffusion Tensor Imaging (DTI) was obtained by using a single-shot EPI sequence on an axial plane. DTI parameters comprised TR/TE = 10330/96 ms, maximum b factor = 700 s/mm2, FOV = 256, matrix = 128x128, cross section thickness = 2.00 mm 30 is made independent directions.

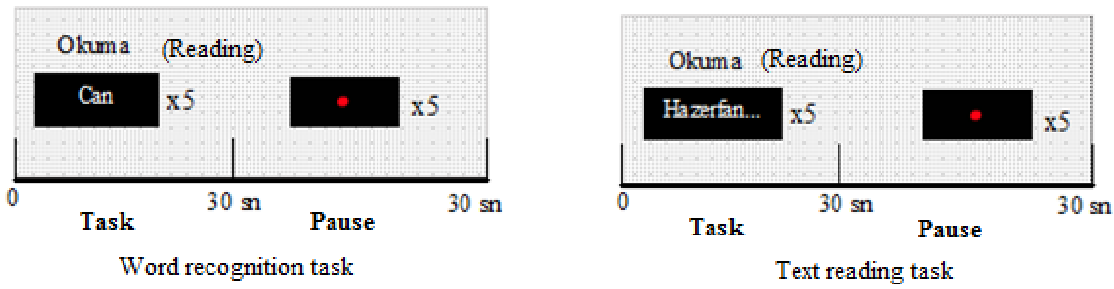

Figure 1. *Schematic display of word recognition task and text reading task.*

Data Collection Instruments

Stroop Test TBAG Form. The Stroop Test is a neuropsychological test designed to reflect frontal lobe activity. The Stroop Test was first developed by John Ridley Stroop (1935) as an experimental task. This test primarily measures the ability to resist aliasing and is considered to be a golden standard (Karakaş, 2011). The Stroop effect occurs when the color used in the writing of a word is different from the color expressed by the word (Karakaş & Doğutepe-Dinçer, 2009). The Stroop test is a measurement tool widely utilized in fundamental scientific works as well as in application areas (Lezak, 1995; Spreen & Strauss, 1991).

Auditory Verbal Digit Span Test-Form B (GİSD-B). Auditory Verbal Digit Span Test-Form B measures digit span retention (Karakaş & Doğutepe-Dinçer, 2009). It is a neuropsychological test developed by Karakaş and Yalın (1993), and can be used to measure the capacity of short-term memory and attention span (Karakaş & Yalın, 2009). This form is an adjusted version of the Auditory Verbal Digit Span Test developed by Koppitz (1977) to estimate short-term memory (Karakaş, 1999).

Digit Span Learning Test. The Digit Span Learning Test (DSLT) was developed by Zangwill in 1943 to measure learning ability and short-term memory capacity. In DSLT, the number of repetitions necessary for a digit span to be correctly repeated from memory is measured. Unlike other digit span learning tests, DSLT can evaluate both short-term memory and general memory capacity. Evaluating the learning aptitude in general, DSLT is a test sensitive to both the hippocampus and mesial temporal area (Karakaş, 2006).

Cancellation Test. The Cancellation Test was designed by Weintraub and Mesulam to measure continuous attention (Mesulam, 1985). Continuous attention refers to the allocation of the mental capacity required by an organism for a given task and continuing the state of paying attention while undertaking an activity (Irak & Karakaş, 2002, p. 169-170). In 2002, a reliability study of the Cancellation Test for child groups in Turkish society was performed. The reliability coefficients of the test were found to range between .45 and .83. These were based on the number of correctly-identified target stimuli, missed target stimuli and erroneously-identified stimuli at the time of scanning. All coefficients were found to be significant (Kılıç, et al., 2002).

Word Recognition and Reading Paradigms. In BOLD and DTI imagings, seven-minute paradigms were developed for word recognition and reading tasks. The paradigm developed for word recognition consisted of 30 words composed of different syllables. The text prepared for reading was developed as a narrative text consisting of 74 words. All the images were collected through the use of the Siemens MAGNETOM Trio Magnetic Resonance Imaging Device.

Table 1. *Data Collection Instruments and Their Intended Use*

Data Collection Instrument	*Intended Use*	*Stage of Study Employed*
Stroop Test TBAG Form	Determination of selective attention and distractive effects	Before and after the program
Auditory Verbal Digit Span Test-Form B (GİSD-B)	Determination of auditory and verbal memory capacity	Before and after the program
Digit Span Learning Test	Determination of learning and memory capacities	Before and after the program
Cancellation Test	Determination of continuous attention and reaction speed ability	Before and after the program
Siemens MAGNETOM Trio Magnetic Resonance Imaging Device	Determination of neural structure by means of neuro-imaging	Before and after the program

Data Analysis

The data collected through the Stroop Test TBAG Form, Auditory Verbal Digit Span Test-Form B, Cancellation Test and Digit Span Learning Test, used to measure cognitive processes, were evaluated within the norm values existing for these tests. For Diffusion Tensor Imaging analyses, FSL (Oxford Centre for Functional MRI of the Brain, Oxford University, UK, (http://www.fmrib.ox.ac.uk/fsl)) and functional brain MRI and SPM software programs were used. All the data collected in the study were descriptively and statistically analyzed. In fMRI (BOLD), voxel numbers exceeding the statistical threshold value standard from the Talaraich-Daemon database and micro-structural changes in DTI were determined by means of functional anisotropy (FA) and apparent diffusion coefficient (ADC) values. Moreover, voxel-based DTI maps were constructed by using the TBSS program package of FSL software (http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/TBSS), so voxels displaying differences in their FA and mean diffusivity (MD) values could be mapped.

Findings

In this section, findings obtained through qualitative and quantitative analyses are presented along with their interpretations as potential answers to the research questions. The findings are presented under two headings - findings related to cognitive processes and findings related to neuro-imaging - in line with the purpose of the study.

Findings Related to Cognitive Processes

The Stroop Test TBAG Form, Digit Span Learning Test, Cancellation Test and Auditory Verbal Digit Span Test-Form B are neuropsychological measurement instruments used to evaluate memory and attention. The Stroop Test TBAG Form measures selective attention and information processing speed, the Digit Span Learning Test measures learning aptitude and memory capacity, the Cancellation Test measures continuous attention and reaction speed, and the Auditory Verbal Digit Span Test-Form B measures attention and memory capacity. General evaluation findings related to neuropsychological test battery before and after the reading program are presented in Table 2.

Table 2. *General Evaluation Findings Related to Neuropsychological Test Battery*

Student	Before the Reading Program	After the Reading Program
Stroop Test TBAG Form		
Student 1	Information processing speed is low Experiences a problem in selective attention	Information processing speed is low
Student 2	Information processing speed is low Experiences a problem in selective attention Impulsivity	Information processing speed is low
Student 3	Information processing speed is low Experiences a problem in selective attention	Information processing speed is low
Student 4	Information processing speed is low Experiences a problem in selective attention	Information processing speed is low
Student 5	Information processing speed is low Experiences a problem in selective attention	Information processing speed is low Impulsivity
Student 6	Information processing speed is low Experiences a problem in selective attention	

Table 2 (Cont.). *General Evaluation Findings Related to Neuropsychological Test Battery*

Student	Before the Reading Program	After the Reading Program
Stroop Test TBAG Form		
Student 7	Information processing speed is low Experiences a problem in selective attention	
Student 8	Information processing speed is low Experiences a problem in selective attention	
Student	**Before the Reading Program**	**After the Reading Program**
Digit Span Learning Test		
Student 1	Experiences problems in memory capacity and learning aptitude	
Student 2	Experiences problems in memory capacity and learning aptitude	
Student 3	Experiences problems in memory capacity and learning aptitude	
Student 4	Experiences a problem in learning aptitude	
Student 5	Experiences problems in memory capacity and learning aptitude	
Student 6	Experiences problems in memory capacity and learning aptitude	
Student 7	Experiences a problem in learning aptitude	
Student 8	Experiences problems in memory capacity and learning aptitude	
Student	**Before the Reading Program**	**After the Reading Program**
	Cancellation Test	
Student 1	Experiences a problem in continuous attention Slow reaction speed	
Student 2	Experiences a problem in continuous attention Slow reaction speed	
Student 3	Experiences a problem in continuous attention Slow reaction speed	
Student 4		
Student 5		
Student 6	Experiences a problem in continuous attention Slow reaction speed	
Student 7		
Student 8		
Student	Before the Reading Program	After the Reading Program
Auditory Verbal Digit Span Test-Form B		
Student 1	Experiences problems in attention and memory capacity	
Student 2		
Student 3	Experiences problems in attention and memory capacity	
Student 4	Experiences problems in attention and memory capacity	

Table 2 (Cont.). *General Evaluation Findings Related to Neuropsychological Test Battery*

Student	Before the Reading Program	After the Reading Program
Auditory Verbal Digit Span Test-Form B		
Student 5		
Student 6		
Student 7		
Student 8	Experiences problems in attention and memory capacity	

When Table 2 is examined it is seen that, before the enrichment reading program, the students' information processing speed was low and they experienced problems in terms of memory capacity, selective attention and continuous attention. When they were evaluated in terms of learning aptitude specifically, it is also seen that they experienced some difficulties. After the reading program, improvements were observed in their attention and memory performances, though information processing speed was relatively unaffected. We can, therefore, argue that many factors related to their reading and learning capacities were ameliorated.

Findings Related to Neuro-imaging

Here, we can turn to our findings obtained through neuro-imagery and the effects of the enrichment reading program on the neural structures of the students. These results are presented as activation findings related to word recognition and text reading tasks before and after the enrichment reading program and as findings related to white matter pathways.

Table 3. *Activation Distribution According to the Parts of the Brain Related to Word Recognition Task, Before and After the Enrichment Reading Program*

Before the Reading Program					
Student	**Occipital Lobe**	**Parietal Lobe**	**Frontal Lobe**	**Temporal Lobe**	**Sub Lobar**
Student 3	Fusiform gyrus	Postcentral lobe Sub-gyral	Superior frontal gyrus Medial frontal gyrus Inferior frontal gyrus Precentral gyrus	Medial temporal gyrus	Claustrum
After the Reading Program					
Student	**Occipital Lobe**	**Parietal Lobe**	**Frontal Lobe**	**Temporal Lobe**	**Sub Lobar**
Student 1	Cuneus Medial occipital gyrus Inferior occipital gyrus				

Table 3. *Activation Distribution According to the Parts of the Brain Related to Word Recognition Task, Before and After the Enrichment Reading Program*

After the Reading Program					
Student	**Student**	**Student**	**Student**	**Temporal Lobe**	**Sub Lobar**
Student 2	Cuneus Medial occipital gyrus Fusiform gyrus	Superior parietal lobule Precuneus	Superior frontal gyrus		
Student 3	Cuneus Medial occipital gyrus Inferior occipital gyrus Superior occipital gyrus		Superior frontal gyrus Medial frontal gyrus Inferior frontal gyrus	Medial temporal gyrus	Claustrum
Student 4	Fusiform gyrus Medial occipital lobe Inferior occipital gyrus	Postcentral gyrus inferior Precuneus Superior parietal lobe	Medial frontal gyrus Precentral gyrus Inferior frontal gyrus Cingulate gyrus Paracentral lobule	Superior temporal gyrus	Lentiform Nucleus Claustrum
Student 5		Postcentral gyrus	Medial frontal gyrus Precentral gyrus		
Student 6	Cuneus precuneus Medial occipital gyrus Inferior occipital gyrus	Superior parietal lobule Precuneus	Precentral gyrus Medial temporal gyrus		
Student 7	Medial occipital gyrus	Superior parietal lobe Precuneus Postcentral gyrus Submarginal gyrus	Superior frontal gyrus Medial frontal gyrus Precentral gyrus Inferior frontal gyrus	Superior temporal gyrus	Insula thalamus

*Before the reading program, no activation was observed in students 1, 2, 4, 5, 6, 7 or 8 in relation to the word recognition task. ** After the application, activation was observed in the anterior lobe of student 4 and activation was observed in the parahippocampal gyrus in the limbic lobe of student 7. *** Following the implementation of the reading program, no activation for student 8 was observed. While evaluating activation status, (cE >10) was taken into consideration.

In examining the activation distributions, no activation was observed in relation to the word recognition task before the reading program, except in student 3. After the reading program, activation was observed in all students except student 8. This activation was primarily observed in the occipital lobe, parietal lobe, frontal lobe, temporal lobe, sub-lobar, anterior lobe and limbic lobe areas. When the occipital lobe activations of student 1, student 2, student 3, student 4, student 6 and student 7 were examined, it appeared that they each displayed medial occipital gyrus activation.

Table 4. *Activation Distribution According to the Parts of the Brain Related to Text Reading Task, Before and After the Enrichment Reading Program*

Before the Reading Program					
Student	**Occipital Lobe**	**Parietal Lobe**	**Frontal Lobe**	**Temporal Lobe**	**Sub Lobar**
Student 1	Lingual gyrus Cuneus	Precuneus	Superior frontal gyrus Medial frontal gyrus Inferior frontal gyrus Precentral gyrus	Superior temporal gyrus Medial temporal gyrus	
Student 2	Lingual gyrus Inferior occipital gyrus		Medial frontal gyrus		
Student 3	Cuneus Medial occipital gyrus Inferior occipital gyrus Superior occipital gyrus	Precuneus Inferior parietal lobe Superior parietal lobe Postcentral gyrus	Inferior frontal gyrus Medial frontal gyrus Superior frontal gyrus		
Student 4		Postcentral lobe Precuneus Postcentral gyrus	Inferior frontal gyrus Medial frontal gyrus Superior frontal gyrus		
Student 5	Cuneus Medial occipital lobe Lingual gyrus		Occipital lobe Lingual gyrus		
Student 6	Cuneus	Precuneus Superior parietal lobule	Occipital lobe, Cuneus		Thalamus
Student 7	Lingual gyrus Cuneus	Superior parietal lobe			
Student 8	Lingual gyrus	Precuneus	Medial frontal gyrus Superior frontal gyrus Cingulate gyrus		Thalamus
After the Reading Program					
Student	**Occipital Lobe**	**Parietal Lobe**	**Frontal Lobe**	**Temporal Lobe**	**Sub Lobar**
Student 1	Cuneus		Superior frontal gyrus Medial frontal gyrus Inferior frontal gyrus		

Table 4 (Cont.). *Activation Distribution According to the Parts of the Brain Related to Text Reading Task, Before and After the Enrichment Reading Program*

After the Reading Program					
Student	**Occipital Lobe**	**Parietal Lobe**	**Frontal Lobe**	**Temporal Lobe**	**Sub Lobar**
Student 2	Lingual gyrus Inferior occipital gyrus Cuneus Medial occipital gyrus	Superior parietal lobe Precuneus Postcentral gyrus	Medial frontal gyrus Cingulate gyrus Medial frontal lobe Inferior frontal gyrus Superior frontal gyrus Precentral gyrus	Superior temporal gyrus	Insula Claustrum
Student 3	Medial occipital lobe Cuneus				
Student 4	Lingual gyrus	Paracentral lobe Superior parietal lobe	Precentral gyrus Medial frontal gyrus Inferior frontal gyrus Paracentral gyrus Superior frontal gyrus Medial frontal gyrus Paracentral gyrus		
Student 5	Cuneus Medial occipital gyrus	Precuneus			
Student 6	Cuneus Medial occipital gyrus	Precuneus	Precentral gyrus Medial frontal gyrus Inferior frontal gyrus		Insula
Student 8	Medial occipital gyrus Fusiform gyrus Lingual gyrus				

When we examined the activation distributions according to the parts of the brain in relation to the text reading task before the reading program, no activation was observed in the occipital lobe, parietal lobe or temporal lobe areas. After the reading program, activation was seen in the occipital lobe, parietal lobe, frontal lobe, temporal lobe, sub-lobar, anterior lobe and limbic lobe areas. When the activation intensity regarding the text reading tasks (cE) is examined, we can see that a decrease occurs after reading the text. While evaluating activation status, (cE >10) was taken into consideration.

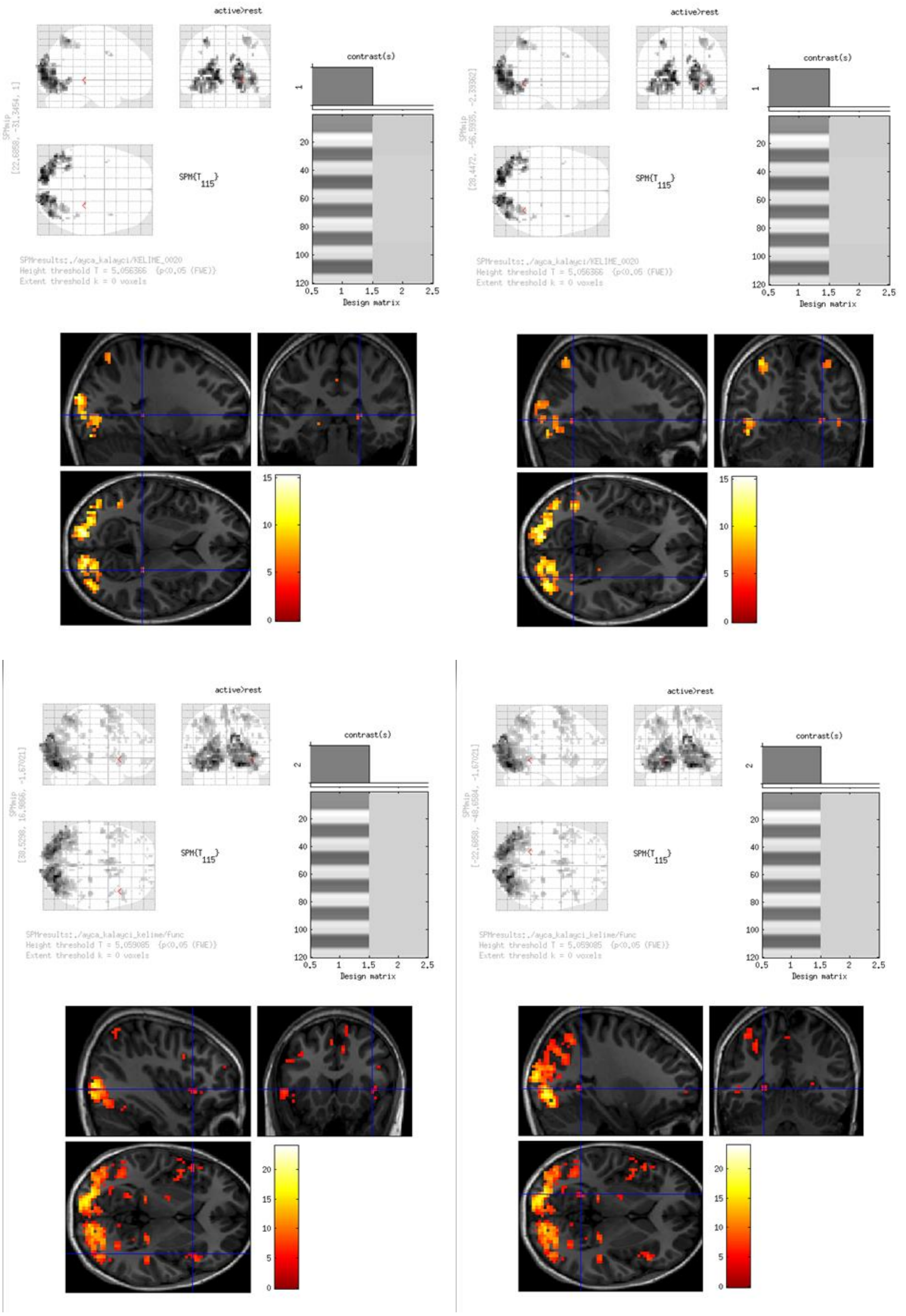

Figure 2. *Activation images before and after the implementation of the reading program (Student 8).*

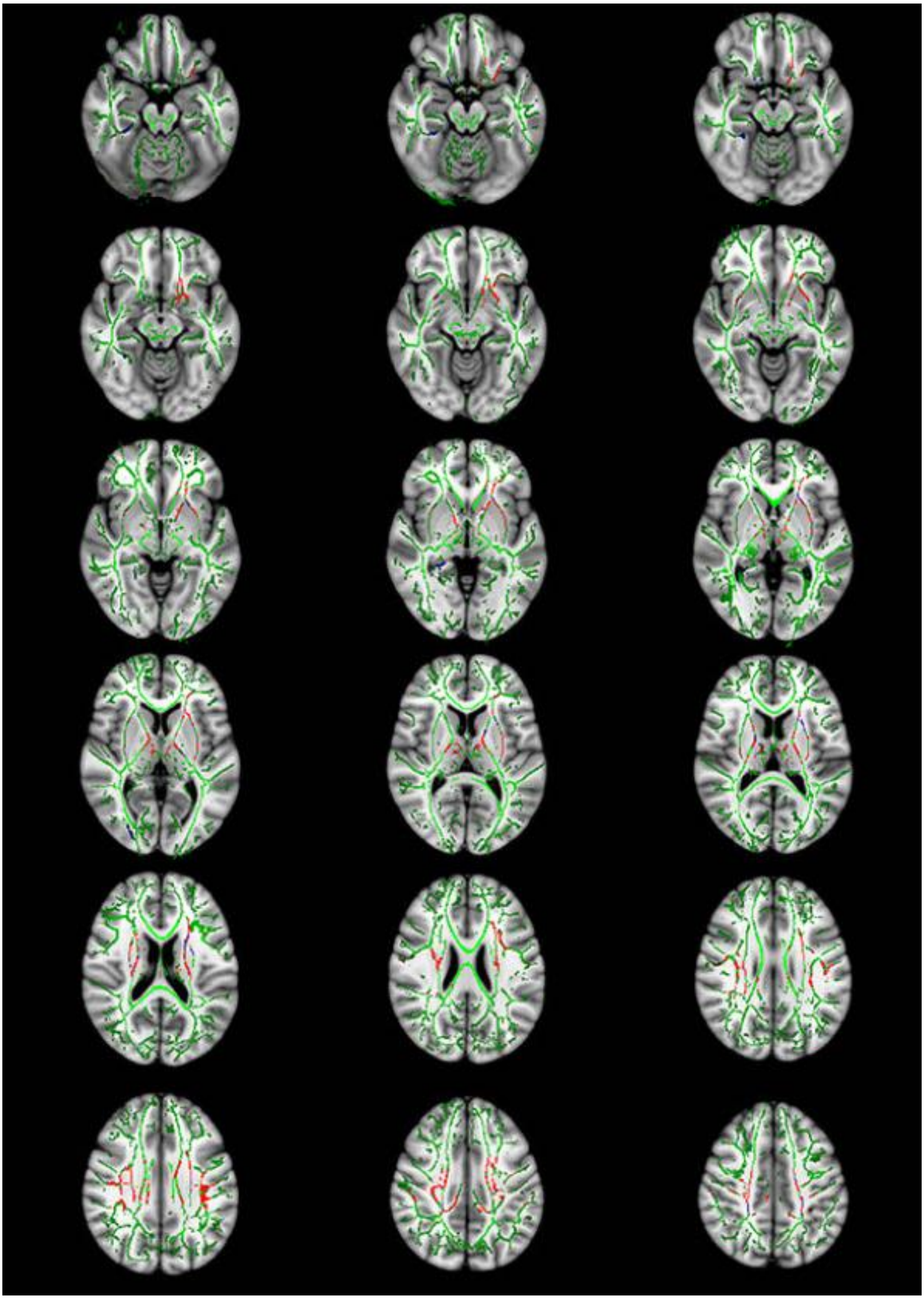

Figure 3. *A map showing statistically-significant FA and MD changes occurring in the white matter before and after the reading program (through diffusion tensor imaging).*

In Figure 3, blue regions show FA increase, red regions show MD decrease and green regions show medium FA skeleton. While FA increase was observed in the right parahippocampal gyrus, left external capsule, hind leg of the bilateral internal capsule and bilateral thalamus, MD decrease was observed in the bilateral uncinate fasciculus, front and hind legs of the bilateral internal capsule and corpus callosum genus. No other regions were found in which FA decrease and MD increase occurred.

Table 5. *Regions Where FA Increase Occurred, with Coordinates*

FA Increase Regions	Coordinates		
	X	*Y*	*Z*
Right parahippocampal gyrus	64	95	53
Left external capsule	118	137	78
Hind leg of left internal capsule	108	111	78
Left thalamus	98	115	81
Right thalamus	83	113	81
Front leg of left internal capsule	106	129	81
Fornix	94	112	87
Right posterior (hind) corona radiata	69	92	108

When Table 5 is examined, we see that the regions where FA increase occurred are the right parahippocampal gyrus, left external capsule, hind leg of the left internal capsule, left thalamus, right thalamus, front leg of the left internal capsule, fornix and right posterior corona radiata.

Table 6. *Regions Where MD Decrease Occurred, with Coordinates*

MD Decrease Regions	Coordinates		
	X	*Y*	*Z*
Right uncinate fascicule	62	136	64
Left uncinate fascicule	114	132	64
Left external capsule	118	137	78
Right external capsule	62	140	78
Front leg of left internal capsule	79	125	78
Front leg of right internal capsule	103	125	178
Hind leg of left internal capsule	108	111	78
Hind leg of right internal capsule	73	116	81
Left thalamus	98	115	81
Right thalamus	83	113	81
Left superior corona radiata	115	122	95
Right superior corona radiata	65	115	95
Left superior longitudinal fascicule	125	129	95
Right superior longitudinal fascicule	59	124	96
Body of corpus callosum	77	117	103

When Table 6 is examined, we see that the regions where MD decrease occurred are the right uncinate fascicule, left uncinate fascicule, left external capsule, right external capsule, front leg of the left internal capsule, front leg of the right internal capsule, hind leg of the left internal capsule, hind leg of the right internal capsule, left thalamus, right thalamus, left superior corona radiate, right superior corona radiate, left superior longitudinal fascicule, right superior longitudinal fascicule and body of the corpus callosum.

Results and Discussion

For this study, an enrichment reading program was administered to a number of students with reading difficulties and it was investigated whether this program had any influence on the students' cognitive processes and neural structures. In this section, the results derived from the findings of the study are presented and discussed in reference to the existing literature.

Results and Discussion Related to Cognitive Processes

As a result of the application of the enrichment reading program, it appeared that some changes did indeed occur in students' ability to focus their attention and their memory development. Tests administered before the implementation of the reading program provided the following findings: the Stroop Test TBAG Form results showed that the students' information processing speed was low and that they had some problems in terms of selective attention; the Digit Span Learning Test findings revealed that the students experienced some problems in terms of learning aptitude and memory capacity; the Cancellation Test scores showed that the students' reaction speeds were low and that they had some problems in terms of continuous attention; and the Auditory Verbal Digit Span Test-Form B revealed that the students experienced problems regarding digit span recall. After the implementation of the reading program, the same test administration showed that the students' problems in selective attention and continuous attention were abolished. However, their low information processing speed remained low.

Selective attention and continuous attention are of great importance during reading for comprehension to be successful. Therefore, when aiming at the elimination of reading difficulties, it is of vital importance to address students' attention problems. In our study, an improvement was observed in the students' performance related to selective attention and continuous attention after the implementation of the reading program. This improvement can be attributed to the students paying greater attention to the task of reading as a result of addressing their reading and reading comprehension difficulties during the application process. When the findings of the current study were evaluated in relation to the status of the memory, it was observed that the performance of visual and auditory memory increased. This might be due to the continuous repetition in the reading program and its focus on reading strategies.

In a 1998 study, Karakelle investigated cognitive processes affecting first reading skills. For this purpose, a series of measurements were conducted to determine children's sensitivity towards letters, phonologic awareness, evaluation of visual-auditory stimuli and verbal ability before the children had acquired reading skills. The children were then followed for one year to evaluate their progress in terms of acquiring reading skills and text reading speed. As a result of this study, it was found that first reading processes are largely related to cognitive processes, but the connection is not yet entirely explained.

In 2010, Özkök-Kayhan conducted a study investigating the reading comprehension skills of students with and without reading difficulties and their relationship to each group's vocabulary knowledge, visual perception, short-term memory and reading speed. Özkök-Kayhan found a significant relationship between reading comprehension and vocabulary knowledge, visual perception, short-term memory and reading speed. Moreover, it was also found that the students with reading difficulties were significantly different from those not having reading difficulties in terms of these competencies.

In 2009, Jiménez et al. aimed to elicit for study the relationship between reading performance, IQ and cognitive processes. The investigation concluded that IQ variation did not lead to a significant difference between the reading performances of the students with and without reading difficulties. However, cognitive process variations did lead to a significant difference in reading performance. Another study looking into the relationship between reading and cognitive processes was conducted by Nevo and Breznitz in 2011. It also found that working memory and phonologic awareness measured before the acquisition of reading skill could predict reading performance.

When these studies focusing on cognitive processes and reading performance are evaluated together, we can see that the content of cognitive processes has often been investigated on the basis of a single variable, such as short-term memory or working memory. However, for the students experiencing reading difficulties, we maintain that a whole host of factors should be evaluated together: short-term memory, cognitive processes like long-term memory, memory utilization capacity, continuous attention and selective attention. Moreover, it can be maintained that cognitive processes cannot account for every dimension of these reading difficulties. Therefore, we argue, neural structures should be evaluated together with cognitive processes.

Results and Discussion Related to Neuro-imaging

When the activation distributions according to the parts of the brain related to the word recognition task were examined before the reading program, no activation was observed. After the implementation of the reading program, activation was observed in the occipital lobe, parietal lobe, frontal lobe, temporal lobe, sub-lobar, anterior lobe and limbic lobe regions. When the activations in the occipital lobe are examined, it can be argued that the activation observed in the medial occipital gyrus is common.

When the activation distributions according to the parts of the brain related to the text reading task were examined before the reading program, activation was observed in the occipital lobe, parietal lobe and temporal lobe regions. After the reading program, activation was observed in the occipital lobe, parietal lobe, frontal lobe, temporal lobe, sub-lobar, anterior lob and limbic lobe regions. When the activation intensities (cE) related to the text reading task were examined, we found that cE values decreased after the reading program. It can also be seen that the amounts of activation occurring during word recognition and reading varied significantly after the reading program. Decreasing activation intensity (cE) and increasing regions of activation can be explained by the students' improving expertise in the reading task.

As for the activation occurring during reading, the findings of the current study indicate that auditory, visual and all other parts of the brain related to language skill should be considered together for the evaluation of reading. At the end of the study, while FA increase was observed in the right parahippocampal gyrus, the left external capsule, the hind leg of the bilateral internal capsule and the bilateral thalamus, MD decrease was observed in the bilateral uncinate fascicule, the front and hind legs of the bilateral internal capsule and the corpus callosum genus.

In 2005, Deutsch et al. conducted a study using the diffusion tensor imaging method to investigate the white matter structures related to reading performance of students aged between seven and thirteen. Word reading performance includes word reading, spelling and fast word naming. The study concluded that FA values of good and poor readers differ in the left temporo-parietal region. Qui et al. (2008) investigated FA and MD changes in white matter related to reading performance during early childhood and late adolescence. They found that with increasing age and reading performance, FA values also increase and MD values decrease. Research investigating the effect of instructional programs carried out to deal with reading difficulties on the brain reported that after the implementation of such instructional programs, the number of the white matter pathways increased.

In our study, after the application of the enrichment reading program, improvements were observed in terms of white matter pathways and activation images. This finding concurs with the findings reported by Keller and Just (2009), indicating improved reading performance and increasing amounts of white matter after the repeated reading application for children. It similarly confirms the findings reported by Shaywitz et al. (2008), demonstrating that, through effective instructional applications, reading problems are reduced and brain activation increases. Ashkenazi et al. (2013) revealed the neuro-biologic basis of mathematic and reading difficulties. In this study, it was emphasized that orthographic and semantic processes result in activation in different parts of the brain. Vogel et al. (2013) stated that reading is directly connected with many regions of the brain (such as the left visual vocabulary form region, left sub-marginal gyrus, angular gyrus, left inferior frontal gyrus and medial temporal gyrus) and that activation in these regions varies depending on age. Baquero, Davis and Cutting (2014) stressed that the parts of the brain related to reading are connected with the bilateral inferior frontal, superior temporal, medial temporal, medial frontal, superior frontal, postcentral gyrus, bilateral occipital cortex, inferior parietal lobule, thalamus and insular. Church et al. (2008) reported that, in children and adults, activation was observed in the temporal cortex in relation to reading tasks. In addition, changes are observed in posterior regions depending on age, reading is linked to the left sub-marginal gyrus, left angular gyrus and bilateral anterior extrastriate cortex, and phonologic operations are related to angular and sub-marginal gyrus.

When the studies dealing with white matter and activation are examined, it is seen that they have mostly focused on adults and compared neural structures of good and poor readers. Within the context of the current study, since each student's state before the implementation of the reading program was accepted as a unique starting point, it has been possible to investigate and explain the effect of the enrichment reading program on the students' neural structures in an individualized way.

When we examine the results reported by neuro-imaging studies focusing on reading and reading, we see that there is some degree of consistency, but also differentiation between the findings. The reason for this can be age, gender, or the complex and multi-faceted structure of reading.

In light of the findings of this study, the following suggestions can be made.

The findings of the study reveal that measurements performed to evaluate reading performance alone are not enough to determine reading difficulties. By its nature, reading and reading comprehension have psychological, neuro-cognitive and neuro-biological bases. Therefore, research into these skills requires the adoption of an inter-disciplinary approach. Standards and norms for the identification of reading difficulties must be established in Turkey, and the scope of this identification should cover attention and memory as well as reading performance.

The current study was conducted with the participation of eight fourth grade students experiencing reading difficulties. Future research may look at the effect of an enrichment reading program on the cognitive processes and neural structures of participants from different age groups and larger samplings.

Neuro-imaging is known to be effective in displaying the structural and functional changes of white matter. In comparing the effectiveness of different treatments and intervention programs for reading difficulties, the use of neuro-imaging can offer novel perspectives for educators and researchers.

During the neuro-imaging in this study, paradigms developed by the researcher (text reading task) were used. There is a need for standardized measurement tools to be used during neuro-imaging so that rich data can be obtained.

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