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Original article

Changes in cognitive functions of students in the transitional period from elementary school to junior high school

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Abstract

Background: When students proceed to junior high school from elementary school, rapid changes in the environment occur, which may cause various behavioral and emotional problems. However, the changes in cognitive functions during this transitional period have rarely been studied. *Methods:* In 158 elementary school students from 4th- to 6th-grades and 159 junior high school students from 7th- to 9th-grades, we assessed various cognitive functions, including motor processing, spatial construction ability, semantic fluency, immediate memory, delayed memory, spatial and non-spatial working memory, and selective, alternative, and divided attention. *Results:* Our findings showed that performance on spatial and non-spatial working memory, alternative attention, divided attention, and semantic fluency tasks improved from elementary to junior high school. In particular, performance on alternative and divided attention tasks improved during the transitional period from elementary to junior high school. *Conclusion:* Our finding suggests that development of alternative and divided attention is of crucial importance in the transitional period from elementary to junior high school.

Keywords: Divided attention; Alternative attention; Executive function; Childhood; Adolescence

1. Introduction

When students proceed to junior high school from elementary school, rapid changes in the environment occur, which may cause various behavioral and emotional problems [1]. One example is the number of Japanese students with school-refusal, which is 7483 out of 1,192,343 in 6th-graders and 22,566 out of 1,199,764 in 7th-graders in 2005 [2]. These behavioral and emotional problems may affect to the development of cognitive function; several cognitive functions may improve from elementary to junior high school. In fact, adolescents with school-refusal showed impairment of cognitive functions such as learning, short-term memory, and attention processing [3,4]. Identifying the improved cognitive functions in this transitional period from elementary to junior high school may be useful for monitoring the development of cognitive functions and picking up the high-risk group for behavioral

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and emotional problems. However, the changes in cognitive functions in this transitional period have rarely been studied.

Executive function, defined as the set of mental control cognitive processes that permit goal-directed behavior, dramatically develops from childhood to adolescence [5]. Levin et al. [6] also highlighted that measurement of executive functions was useful for studying the development of cognitive function in children and adolescents. One source of evidence stems from studies of development and aging that include executive function tasks known to involve intact frontal functioning for efficient performance. Anderson et al. [7] conceptualized executive function as comprising three separable, but integrated, components: (a) attentional control – selective attention and sustained attention; (b) cognitive flexibility – working memory, attentional shift, self-monitoring, and conceptual transfer; and (c) goal setting – initiating, planning, problem solving, and strategic behavior. The basic neural structure subsuming these executive functions may be the same regardless of developmental stage; however, important differences exist with respect to their maturity [7]. Therefore, assessment of executive function should be performed carefully in each conceptualized factor. In the field of development of executive function, for example, age-related gain has been reported in inhibitory control [8], spatial [9] and non-spatial working memory [10], task switching [11], adaptive problem solving [12], and various other planning and problem-solving tasks [13]. Executive function is also related to control of attention [14], an important element of information processing that is embodied in the central executive component in theoretical conceptions of working memory [15]. Attentional competency develops steadily through early and late childhood, perhaps due in part to the development of core processing resources [16]. In the literature on normal cognitive development, there are two general hypotheses: that as children grow older, they have more resources [17] or that they are able to utilize their existing resources more efficiently [18]. With more resources or increasing control over resources, they become able to pay attention to more stimuli, allocate their attention more efficiently in accordance with task demands, and generally use and benefit from more sophisticated strategies in complex activities such as dual tasks [19].

Based on these findings, we extensively investigated a variety of cognitive functions, focusing in particular on executive function and control of attention around the transitional period from elementary to junior high school.

2. Materials and methods

2.1. Subjects

Subjects were recruited from an elementary school and a junior high school in Hyogo Prefecture. Most of the students in this elementary school proceed onto the junior high school. Forty-five subjects with medical illnesses, such as allergic disease, asthma, thyroid disease, nephritis, diabetes mellitus, heart disease, anemia, myodystrophy, and epilepsy, were excluded from analyses. Performance on cognitive function tests in a total of 317 elementary school and junior high school students were analyzed in the present study, including 54 4th-grade [9.8 $\pm$ 0.4 years of age (mean $\pm$ SD), 28 females and 26 males], 55 5th-grade (10.7 $\pm$ 0.5 years of age, 30 females and 25 males) and 49 6th-grade (11.7 $\pm$ 0.4 years of age, 27 females and 22 males) students in elementary school and 65 7th-grade (12.6 $\pm$ 0.5 years of age, 41 females and 24 males), 38 8th-grade (13.5 $\pm$ 0.5 years of age, 9 females and 29 males) and 56 9th-grade (14.6 $\pm$ 0.5 years of age, 25 females and 31 males) students in junior high school. The protocol was approved by the Ethics Committee of Osaka City University (approved number: 1012). All subjects and their parents gave written informed consent for participation in the study.

2.2. Cognitive function tests

Subjects performed paper-and-pencil and computerized cognitive tests. The paper-and-pencil cognitive tests consisted of a list learning test [20], KANA pick-out test [21], semantic fluency test [22], figure copying test [20], digit span forward test [23], symbol digit modalities test [24], and list recall test [20]. The paper-and-pencil cognitive tests were performed in this order. The KANA pick-out test, which was developed in Japan, performed with paper-and-pencil, and is widely used for the evaluation of dementia in older. The validation and reliability of this test was confirmed [25]. Recently, divided attention in accordance with the KANA pick-out test plays a crucial role not only in dementia but also in children's disorder, such as patients with childhood chronic fatigue syndrome [4]. Other cognitive tests are included in repeatable battery for the assessment of neuropsychological status [20]. The validation and reliability of this cognitive battery were confirmed [26].

The list learning test was used to assess immediate memory. This test consists of immediate recall of a 10-item list of words over four learning trials. The words are semantically unrelated, characterized by early age of acquisition, relatively high-imagery, and as phonetically unique as possible. The full score for this test is 40.

The KANA pick-out test requires parallel processing of reading and picking out of letters, and also requires appropriate allocation of attentional resources to the two activities. Subjects are shown a short story written in Japanese KANA characters. They are required to find as many vowel symbols as possible within 2 min, while understanding the meaning of the story. Two min after the start of the test, they are asked 10 questions about the contents of the story over a 2 min period. The