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Original article

Developmental trajectories for attention and working memory in healthy Japanese school-aged children

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Abstract

Objective: The aim of this study was to investigate the developmental trajectories of attention, short-term memory, and working memory in school-aged children using a 10 min test battery of cognitive function.

Methods: Participants comprised 144 typically developing children (TDC) aged 7–12 years and 24 healthy adults, divided according to age into seven groups (12 males and 12 females for each age group). Participants were assessed using CogHealth, which is a computer-based measure composed of five tasks. We measured attention, short-term memory, and working memory (WM) with visual stimulation. Each task was analyzed for age-related differences in reaction time and accuracy rate.

Results: Attention tasks were faster in stages from the age of 7–10 years. Accuracy rate of short-term memory gradually increased from 12 years of age and suddenly increased and continued to increase at 22 years of age. Accuracy rate of working memory increased until 12 years of age. Correlations were found between the ages and reaction time, and between ages and accuracy rate of the tasks.

Conclusion: These results indicate that there were rapid improvements in attention, short-term memory, and WM performance between 7 and 10 years of age followed by gradual improvement until 12 years of age. Increase in short-term memory continued until 22 years of age. In our experience CogHealth was an easy and useful measure for the evaluation of cognitive function in school-age children.

Keywords: Attention; Working memory; Short-term memory; Developmental trajectories; Typically developing children

1. Introduction

High-level cognitive function is required for humans to live in society, and when cognitive function works efficiently, people are able to pursue an adaptive social lifestyle. Working memory (WM) plays an important role in efficient high-level cognitive function [1], as it temporarily retains information while also processing it. This distinguishes WM from memory, which only retains information. Past studies have reported that WM generally has limited capacity [2], and that this capacity varies according to the individual. WM increases from childhood to adolescence [3], and

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decreases during old age [4]. A study investigating the relationship between WM capacity and response inhibition tasks showed better performance by the high WM capacity group than the low group in antisaccade tasks and Stroop tasks, which involve inhibiting dominant reactions [5]. Research results such as these suggest that WM maturation and decline is closely related to school and social lifestyle.

At the core of WM is the attentional control system known as the central executive [1,6]. Attention is thought to comprise components of sustained attention, selective attention and divided and alternating attention [7–9]. Attention, which is thought to mature over a multistage process in which specific components develop during different periods, has been theorized to mature from childhood to adolescence [10–13]. A certain amount of processing resources are required for attentional function of the central executive to work efficiently, and without the necessary capacity it cannot function well. Efficient processing means that attentional function can be used to retain many processing resources. However, poor efficiency where a large amount of resources are used leaves fewer resources available for retention. Thus, the distribution of activation between processing and retention is said to be a trade-off relationship, as WM processes activate information while retaining it [14].

Previous studies have reported that both WM and its central executive system of attention develop during childhood. However, few reports have investigated how WM and attention mature throughout childhood and whether sex-related differences exist. Delays in the development of WM and attention can lead to maladjustment in school and society, and are linked to the onset of secondary disabilities. Therefore, evaluation of age-specific WM and attention development is necessary.

The CogHealth battery has been validated for the assessment of cognitive function in attention deficit hyperactivity disorder [15,16]. It comprises five tasks, for example visual attention, memory, and working memory, and this battery requires only 10 min. The CogHealth battery was developed specifically so that repeated performance on the tests does not give rise to improvement in performance in either healthy school aged children or in children with ADHD [16]. These performance measures were used because (1) they are the most appropriate for measuring cognitive changes in children with minimal practice effects, (2) they yield normal distribution, and (3) they allow enough variation in performance to detect declines and improvements in performance. The assessment of cognitive function in children is complicated and time consuming.

The aim of this study was to investigate the developmental trajectories of attention, short-term memory, and working memory in typically developing Japanese children using a 10-min computer-based test battery of cognitive function.

2. Methods

2.1. Participants

In total, 144 typically developing children 12 years of age were selected from four primary schools, and 24 healthy adults 22 years of age participated as paid volunteers. They were divided according to age into seven groups of 24 subjects (each comprising 12 males and 12 females). An experienced pediatric neurologist and psychologist obtained the participants' medical history and performed neurological examination. The participants' parents were asked to respond to a Strengths and Difficulties Questionnaire (SDQ) regarding their children [17]. The children had no history of visual impairment or neuropsychiatric disorders and were not being administered any medication. Eligibility criteria for TDC included an absence of abnormalities in development, behavior (total needs in SDQ subscale was low), academic difficulty, and neurological findings. Informed consent was obtained from all participants and parents after the details of the study had been fully explained. The Ethical Committee of Kurume University School of Medicine approved the study protocol.

2.2. Tasks

All tests were conducted with CogHealth using playing cards that appeared on a computer screen. Each task is shown in Fig. 1. CogHealth is used to assess therapeutic effects [15,16,18,19] and behavioral therapy effects [20] in children with ADHD. It assesses five types of cognitive functions including visual attention and WM, which can be used to conduct an objective assessment, and it takes approximately 10 min to complete the test. The cognitive paradigms operationally defined in the brief CogHealth battery (other than the monitoring task) are that they have an acceptable construct and criterion validity in a neuropsychological context [21,22]. One of the advantages of CogHealth is that it can be used repeatedly because it has no learning effects. Because of these features, we felt that CogHealth was suitable as a tool for measuring and monitoring therapeutic effects, including behavioral therapy and pharmacotherapy in individuals and groups during childhood when cognitive function is developing.

(1) Detection: A task measuring sustained visual attention.
(2) Identification: A task measuring selective visual attention function.