Developmental Psychology
1977, Vol. 13, No. 5, 543-544

Age Differences in the Speed of Processing: A Critique

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This paper questions the assumption that a central processing deficit exists in the speed of performing mental operations by children as compared to adults. Two hypotheses were proposed. First, developmental differences in reaction time need not be due to differences in the speed of elementary mental operations. Data from the Sternberg scanning paradigm were cited as evidence. Second, above and beyond reaction time differences attributable to peripheral processes, further differences can be accounted for by children's use of inefficient processes. Data from quantification studies were provided as supportive evidence.

It is commonly observed that children process information more slowly than adults. This is true for many speeded tasks where reaction time (RT) is the major dependent variable. Developmental differences are often quite substantial in tasks such as tachistoscopic recognition, visual search, reading, mental arithmetic, mental rotation, etc. To take one concrete example, eye movements from one fixation to another average almost twice as fast in adults as 8-year-olds (270 vs. 411 msec; Miller, 1969).

Such age differences in processing speed have often been identified with a central deficit in the speed of elementary mental operations. Wickens (1974), for example, suggested that "some portion of the age differences in RT is due to differing limits in central processing speed." This assumption was compelled by "the failure of any studies in the literature to obtain an equality in RT between adults and children" (Wickens, 1974, p. 743).

It seems necessary, however, to distinguish between three possible causes of slower RTs in children. First, children may take longer to perform individual elementary mental operations, where an elementary mental operation can be briefly defined as an irreducible process such as *compare, find next,* etc. (Chase, 1977). Secondly, children may not have an efficient organization of processes to perform a particular task. The procedure used to organize a sequence of mental operations is usually termed a control process (e.g., rehearsal, counting). Finally, when one discusses a central processing limitation in children, it is important to differentiate processing from nonprocessing limitations, such as increased motor time, inability to maintain set, rate of information loss from short-term memory (STM), and less accessible or deficient knowledge base in semantic memory, to name a few. These latter factors have been discussed in the literature (Chi, 1976; Wickens, 1974). This paper addresses the former two issues, and it proposes to show that developmental differences in RT (a) do not necessarily mean slower elementary mental operations, and (b) often reflect different control processes across age groups.

The best illustration of an estimate of an elementary mental operation where abundant developmental data have been gathered is the Sternberg (1966) STM scanning task. This task is designed to measure the time to compare an encoded stimulus with a set of memorized stimuli in STM. In this task, the subject is presented with a memory set of from 1 to n items, where n is generally kept below the memory span. Then a probe is presented and the subject's task is to indicate as quickly as possible the presence or absence of the probe in the memory set. Reaction time is generally an increasing linear function of n, and the slope of this function is an estimate of the comparison process.

This paradigm is particularly suitable for studying adult–child differences in RT for various reasons. Foremost, peripheral differences such as encoding and movement times can be partialled out of the scanning rate estimate because they influence the intercept and not the slope of the linear function. Secondly, one can independently assess the scanning processes used by children and adults by examining the RT patterns across age groups. Finally, the task is simple to run in children, and it does not require any verbal responses nor verbal stimuli.

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Most of the developmental studies conducted with the Sternberg paradigm have used children in the 8–14 age range, and no significant developmental differences were found in the memory scanning rates (Dugas & Kellas, 1974; Harris & Fleer, 1974). The single study conducted with 5-year-olds also arrived at the same conclusion (Hoving, Morin, & Konick, 1970). The data further suggest that the same serial and exhaustive scanning process was used by all age groups. Thus, here is an example of a task in which the speed of an elementary mental operation—*compare*—is similar for adults and children, even though the peripheral processing time (the intercept) is greatly retarded in children (688 vs. 306 msec for third graders and adults, respectively; Harris & Fleer, 1974).

Chi and Klahr (1975) measured the time it took adults and 5-year-olds to quantify random dot patterns ranging from 1–10. In the 4–10 dot range, RT is a linearly increasing function of the number of dots to be quantified. The slope for children was around 1 sec, three times that of adults. Chi and Klahr did not conclude that the central processing speed of children was slower, but that adults and children were using different processes to quantify a group of dots. It was hypothesized that adults grouped the large set of dots into smaller subsets, subitized each subset, and added. This hypothesis agrees with adults' introspection and has since been confirmed in the literature (Chase, 1977). This strategy obviously does not apply to 5-year-olds, since they can hardly add. The linear function for children is due to a simple counting process. Hence, it is not meaningful to say that children have slower mental operations, only that children apply different mental processes.

A similar interpretation applies to mental arithmetic. Groen and Parkman (1972) measured the time it took adults and 6-year-olds to add two digits. They found that the same basic function describes both sets of data, namely that RT was a linear function of the smaller digit, with a slope of 410 msec for first graders and 20 msec for adults. The evidence suggests that children simply set a mental index equal to the larger digit and then count upward at the rate of about 410 msec per count, until they have counted a number of times equal to the smaller digit. It seems unlikely, however, that adults increment at a rate of 20 msec per count, because the rate of implicit speech is upwards of 100 msec. The most likely explanation is that children count and simultaneously keep track of an index, but adults retrieve stored information about sums directly. Access to the answer in the semantic network could be a function of the smaller addend. This example shows that the processes used to add can be different between age groups.

This paper suggests that there is no need to postulate age differences in the speed of central processing, especially when evidence exists to show that an equality can be obtained in the time to perform an elementary mental operation such as *compare*, in the Sternberg paradigm. Furthermore, when RT differences do arise, they can often be accounted for by the use of a different aggregate or sequence of mental operations by children and adults, that is, by different control processes.

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(Received February 14, 1977)