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Is there a developmental gap in visual search for children with reported attention problems?

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ABSTRACT

We report an analysis of developmental patterns in visual search for 6 to 12-year-old children. A typically developing sample of 1442 children is compared with two samples (N = 1160 and N = 947) of children with teacher-reported attentional problems. Inclusion criteria for these two groups are low academic achievement and probable attention problems as the reason for the low achievement. The three groups completed DiViSA, a computerized visual search test. Obtained data show two patterns of visual search development. Children with teacher-reported attentional problems show hastiness, inaccuracy and slowness. Children with attention problems perform as if they were younger, in terms of visual search. Data show a performance lag in visual search of about two to three years at every tested grade for the children with attentional difficulties. However the development patterns of children with and without attention problems are parallel, showing improvement with age in both groups.

1. Introduction

Our present purpose is to study the development of schoolchildren with regard to visual selective attention. We compare the performance, in a visual-search attention test, of two samples of children from 6 to 12 years old. One sample comprises typically developing children, who have normal performance levels in school, and the other is a sample of children who, according to their teachers' criteria, could have attentional problems. Inclusion criteria are low academic achievement and probable attentional problems as the reason for the low achievement. We will first review the concept of attention and then describe the studies designed to analyze its developmental pattern in typical children and those with purported attentional difficulties.

Attention-deficit hyperactivity disorder (ADHD) is defined as a pattern of developmentally incoherent attention and behavioral outcomes (DSMIV-TR). The term “developmentally incoherent” usually refers to a poor fit between the chronological age and the behavior being measured. Norms for school-age children are necessary to test for any developmental gap between ADHD children and their schoolmates. However, attention is a multifaceted construct and so the tasks and tests used to assess the developmental patterns are diverse, ranging from school-type tasks, such as the Selective Attention Measures from the Test of Everyday Attention for Children (Manly et al., 2001) to laboratory tasks such as the ANT battery for children (Rueda et al., 2004). Each test or task employed taps one attentional facet (e.g., selective attention, attentional control, or sustained attention), which could develop in a specific and perhaps independent way (Quiroga, Santacreu, Montoro, Martínez-Molina, & Shih, 2011). With this diversity in mind, it is important to focus on the facets of attention most directly related to daily life. In this sense, visual search tests have been proposed to be among those with the highest ecological validity to assess the efficient selection of relevant objects people do to attain their everyday goals (Peelen & Kastner, 2014). This high ecological validity refers to the fact that, in our daily lives, adults and children frequently direct attention toward objects to select those that are relevant or useful for their purposes, thus using their visual search ability very frequently (e.g., searching for a pair of socks, looking for the right books to put in a backpack, trying to find relevant information on a screen or chalkboard, seeking a friend during recess and so on). Therefore, measuring the typical developmental pattern of visual search performance will let us operationalize what “developmentally incoherent” means for selective attention.

To measure the visual-search developmental-pattern, Klenberg, Korkman, and Lahti-Nuuttila (2001) used the neuropsychological battery NEPSY and tested 400 children aged 3 to 12 years old. In the Visual Search Test from the NEPSY, the child must search, as quickly as possible, for target pictures in a random array. The test provides an efficiency index (Score = [(Correct responses − Commission

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Errors) ÷ Performance Time]). Obtained age effects on the Visual Search Test were large and continuous from age 6 to 12. This monotonic developmental pattern refers to the global efficiency index, but no data were reported about the development of this score's components (i.e., correct responses, commission errors and performance time). In this way, identical efficiency-index values can be obtained with different values for correct answers, commission errors and performance time. For example, an efficiency index of 0.13 can result from 75 total correct answers (from a maximum of 98), 10 total commission errors and a total performance time of 300 s (from a maximum of 420), but it can also result from 60 total correct answers, 8 total commission errors and a total performance time of 400 s. In the first example, the child's performance is relatively quick with a high proportion of correct answers, while in the second the child is relatively slow and provides fewer correct answers. For this and other reasons, the increasing developmental pattern for visual search that many researchers have reported should be analyzed into its components, identifying how much of the trend is due to increasing accuracy and how much to increasing speed. Knowing about the different components' developmental pattern would help practitioners to design and precisely focus educational or clinical interventions.

To our knowledge, no study has determined the developmental pattern for children with ADHD on the NEPSY Visual Search test. Thus, it remains to be determined whether the developmental pattern for visual search in children with attention problems differs, or not, from that of children with typical development.

From a different perspective, Lehman, Naglieri, and Aquilino (2010) administered the CAS (*Cognitive Assessment System*; Naglieri & Das, 1997) to 2200 children from 5 to 15 years old. This Battery includes two genuine Attention Tests: the *Expressive Attention Test* (testing the Stroop Effect with two different tasks depending on age) and the *Number Detection Test* (a visual search task). The *Expressive Attention Test* consists of three pages. On the first one, the child reads color words; on the second page the child names the colors of printed rectangles and on the third page, the child names the ink color of printed color words. Performance on this test is summarized with a ratio of accuracy and time taken to complete the task. The *Number Detection Test* consists of several pages of numbers printed in different formats. The child must find a target stimulus on each page. Each page contains 25% targets. Performance on this test is summarized with a ratio of accuracy to total time taken to complete the task. Lehman et al. (2010) tested for age effects, computing effect sizes from adjacent age groups. Cohen's d was interpreted as a measure of rate of change. Obtained Cohen's ds were large for the *Number Detection Test* (from 5 to 6, $d = 1$; from 6 to 7, $d = 0.80$; from 9 to 11, $d = 0.80$; from 11 to 13, $d = 0.70$; from 13 to 15, $d = 0.70$ and from 15 to 17 $d = -0.20$) but moderate for the *Expressive Attention Test* (from 5 to 6, $d = 0.60$; from 6 to 7, $d = 0.50$; from 9 to 11, $d = 0.50$; from 11 to 13, $d = 0.60$; from 13 to 15, $d = 0.60$ and from 15 to 17, $d = 0$). These results support the idea that different tasks measure different attentional facets and that tasks based on the Stroop Effect are not specifically assessing selective attention. Another important point is that in the study by Lehman et al. (2010) some age groups were not represented (e.g., 8, 10, 12, 14, and 16 years). Despite this limitation, the results from Lehman et al. showed a continuous change (more efficiency) in visual search from ages 5 to 15.

The CAS has also been used by Naglieri, Goldstein, Iseman, and Schwebach (2003) to assess a group of children with a diagnosis of ADHD that were matched on age, gender, race, region, community and parent educational-level, with a group of children with a diagnosis of Anxiety/Depression. The whole CAS battery (including three tests of Attention: *Expressive Attention*, *Number Detection* and *Receptive Attention*) was administered to both groups. From the three attention tests, a Global Attention score was computed. As a whole, the 25 ADHD children (ranging from 7 to 12 years old) showed lower scores on Planning ($d = 0.59$) but not on Attention ($d = 0.09$), when compared to Anxiety/Depression children. Effect size was larger when ADHD children were compared with normative data on Planning ($d = 0.85$) than when compared with normative data on Attention ($d = 0.25$). These data show a similar level of efficiency in Visual Search for ADHD children when compared with normative data, which is very unexpected. As suggested by Wassenberg et al. (2008), tasks' features might account for this result because the authors computed a global score, from the three administered attention-tests. That score does not allow differentiating the ADHD group's performance on each task. In addition, Naglieri et al.'s groups were very small to test for developmental effects. As a result, it is not possible to know whether the efficiency level is similar at all ages (from the age range considered) or is just an artifact due to the global score used (the average for the three tests). In fact, studies comparing typically developing children with those with ADHD often include small sized groups covering a wide age range (Mullane & Klein, 2008). Such comparisons severely limit testing for developmental effects. Naglieri et al. (2003) reported a small developmental gap between ADHD children and their schoolmates. However, it needs to be clarified whether this developmental gap is continuous, of equal size at all ages from 6 to 12 (parallel developmental patterns); or discontinuous, having a higher rate of change at some developmental point from ages 6 to 12 (nonparallel developmental patterns).

One of the most common tests of selective attention is the *d2* (Brickenkamp, 2002). It asks participants to cross out any letter "d" with two marks above it or below it. Surrounding distractors are similar to the target stimulus, for example a "d" with three marks. Using this test, Wassenberg et al. (2008) assessed 451 children from second to sixth grade. Their results showed a linear increase in speed (number of items processed per unit of time) by school-grade, a decrease of impulsivity (number of commission errors divided by processing speed) until fourth grade and a stable level of inattention (number of omission errors divided by processing speed) from second grade on. More importantly, *d2* is a test that must be completed by rows (a very organized stimuli field), with the time allowed to process each row limited to 20 s. The way to complete the *d2*'s items does not allow for flexibility in the way children organize the visual search. Accordingly, results from this test could be different than results obtained in other tests in which children have to look for a target in an unorganized stimuli field.

To sum up, the visual-search and attention studies reviewed here show several limitations. First, a continuous change in visual search efficiency (global score) from childhood to adolescence for typically developing children has been obtained, but little is known about the developmental pattern of the components of the efficiency index computed in the visual search tests used (correct answers, commission errors, and performance time), except for a very organized stimuli field (*d2* Test). Second, a small effect size has been obtained when comparing a typical development group with a diagnosed ADHD children group with very different ages, but there are no data regarding the developmental trajectory for visual search for each age, from 6 to 12 years old, in children with attention problems. Some of these limitations might be due to ADHD children having been considered as a unique group but consisting of children of different ages, highlighting their "clinical" feature instead of considering both, their "clinical" level and their developmental one. To overcome these two limitations, it is necessary to analyze larger samples of children. To determine the developmental patterns of both groups and to make comparisons between them, a large children sample from ages 6 to 12 with attention problems and another large sample of school-age children from the same age range, both of which complete the same visual search test, are needed. This way, effects of pertaining to one of these groups, with or without attentional problems, their respective developmental trends, and any possible interaction can be analyzed. Moreover, the selected visual search test must provide separate scores for correct answers, commission and omission errors, and performance time, in order to be able to study the developmental trajectory of each one of them.

DiViSA (*Simple Visual Discrimination Test of Trees*) is a computerized visual search test (Santacreu, Shih, & Quiroga, 2011) that consists of