# TEMPORAL SUSTENANCE OF ATTENTION IN CHILDREN DURING INFANCY USING REACTION TIME MEASURES

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## Abstract

*Sustained attention corresponds to the ability to maintain attentional focus on an activity for a longer period with the same consistency pattern. Knowledge about the development of mental abilities is essential for the understanding of how cognitive processes establishes throughout development and their relation to brain organization. This study aims to analyze the ability to sustain attentional focus in time in children of different age groups. The study included 78 children aged 6 to 11 years old (44 girls and 34 boys), enrolled from the 1st year to the 5th year of private school in São Paulo, Brazil. Each participant was instructed to fixate the gaze at the fixation point (FP), prepare to respond after it changed color to blue and respond as quickly as possible to the occurrence of the target (0.3-degree square superimposed to the central point) pressing the space bar, measuring the reaction time (RT). The target would come after one of 12 equal possible time intervals (100; 400; 700; 1000; 1300; 1600; 1900; 2200; 2500; 2800; 3100 and 3400 ms) in milliseconds. Multifactor ANOVA with repeated measures results demonstrated a significant effect ($F(4, 73) = 13.001$, $p < 0.001$) for Schooling. It was also verified a systematic decrease of the RT as a function of cue-target time interval increase ($F(11, 803) = 26{,}708$, $p < 0.001$). In this manner, we observed a systematic decrease in the RT due to the increase in schooling and in function of increase cue-target time interval.*

**Keywords:** Sustained attention; Development; Infancy; Neuropsychology

## 1. Introduction

Sustained attention corresponds to the ability to maintain attentive focus on an activity for a longer period with the same consistency pattern. Some authors consider it synonymous of concentrated attention (Coutinho, Mattos, Abreu, 2010). The tests usually used to investigate sustained attention typically require direct attention to a source of information for extended periods. In these tasks, the deterioration in performance over time indicates the loss or instability of concentration (Carreiro & Teixeira, 2012).

During the process of infancy development, the nervous system maturation contribute to the effectiveness increases of cognitive processes and behavioral control. Consequently, the children's attention abilities improves as they grow up (Carreiro et al., 2015, Lellis et al., 2013).

The theme of visual attention development in childhood has attracted a growing interest within the scientific literature. Colombo (2001) carried out a review that described that child's ability to pay attention is quite limited at the beginning of development and increases at different periods. First, the newborn spends much of his time in sleep states and less than 20% in alert states. Subsequently, the baby increases its alertness due to external stimuli. Posner et al. (2014) add that the caregiver provides much of the regulation of the baby in this early stage of childhood. Behaviors of holding, balancing, calming or directing the attention of the child is a common practice that provides means of raising and lowering sensory stimulation.

According to Gazzaniga et al., (2006) the newborns trace objects in motions, but still does not show a gentle search with eye movements. Instead, they use a saccadic pattern of ocular movement (small jumps in fixation from one point to another) to follow a moving object. In a few weeks of life the babies distinguish the face of their mothers from the face of other women. Thus, the children with one month of life are able to fix and to be attentive to any stimulus. Babies are more likely to fix mainly for eyes, but between 6 and 12 months, when language learning is more prominent they are more likely to orientate to the mouth (Posner et al., 2014).

Thus, visuospatial orientation develops with the visual system itself. Once babies are able to fix their gaze, they move on to a phase where they look at objects for a long time, primarily at those with a strong contour. This period ends around four months of age, when children begin to control their orientation towards new stimuli (Nahas & Xavier, 2006; Colombo, 2001).

Another factor about the development of the baby pointed out by Colombo (2001) is that between two and four months he begins to have the capacity to withdraw attention from things. If the baby is looking at one object and shifts its gaze to another, it will be more difficult to look back at the first object. We can call this process inhibition of return. Lellis et al. (2013) analyzes voluntary and automatic orienting of attention during childhood development. Children (from 6 to 10 years old) were asked to press a key in response to a visual target presented in a previously oriented position (voluntary orienting) or after a peripheral unpredictable cue (automatic orienting). A systematic reduction of reaction times was observed in older children in both experiments. They also observed the appearance of Inhibition of Return because of the maturation of the attentional system derived from childhood development, which contributes to more effective exploration of the environment.

Multidimensional stimuli can only be perceived together at about four to five months of age.

Smaller babies pay more attention in shape and color and are more likely to scan the outline of objects. Babies between six and nine months old tend to pay more attention to the characteristics of the objects than to the surrounding environment (Colombo, 2001). Xie and Richards (2017) measures event-related potentials (ERPs) and cortical source analysis to examine the effect of covert orienting and sustained attention on 3- and 4.5-month-old infants' brain activity in a spatial cueing paradigm. They observed that infant sustained attention modulated infants' brain responses in covert orienting by enhancing the ERP responses during sustained attention. These discoveries suggest that the neural mechanisms that underpin covert orienting already exist in 3- to 4.5-month-old, and they could be facilitated by infant sustained attention.

A study by Dye and Bavelier (2010) tested children and adolescents aged 7 to 17 years and adults aged between 18 to 22 years in three specific attention skills such as visuospatial attention, keeping attention focused over time and directing attention for visual objects. Participants were asked to locate a simple target among the distractors and the findings are that children between the ages of six and eight are still heavily influenced by distractors during search tasks. They also describes that the maintenance of the sustained attention improves as a function of the school grade and student age. Another conclusion of this study is that children and adults playing video games performed better than expected than non-action video game players, indicating that training can modify fundamental aspects of visual attention and detect peripheral targets in video games (Dye & Bavelier, 2010).

Therefore, knowledge about the development of mental abilities is essential for the understanding of how cognitive processes are established throughout development and are related to the organization and functioning of the brain in the adult human being, so, the objective of this study is to analyze the ability to sustain attention in time in children of different age groups.

## 2. Method

### 2.1 Participants

The study included 78 children aged 6 to 11 years old (44 girls and 34 boys), enrolled from the 1st year to the 5th year of Elementary School in a private school in São Paulo, SP (Table 1A and 1B). For the initial selection of the participants, all 15 school classes from different grades were invited. The selected students took a letter of invitation requesting the presence of a parent to a meeting at school to explain the research and evaluation process. At this meeting, the signing of the free and informed consent form was requested so that the subject could participate in the evaluation. All methodological procedures were approved by the Committee on Ethics in Research Involving Human Beings of Mackenzie Presbyterian University, and by this committee, were approved under the procedures CEP / UPM No. 1229/04/2010 and CAAE No. 0037.0272.000-10.

The following criteria for inclusion of subjects in the research were: (1) Authorization of parents; (2) Score on Attention Deficit Disorder and/or Hyperactivity Disability, version for teachers, by Benczik (2000) that does not characterize attention or hyperactivity deficits; (3) Intellectual level within the average or above the average, evaluated by the estimated IQ from the application of the cubic subtests and WISC III vocabulary. Exclusion criteria were the existence of intellectual disability, severe motor impairment and academic performance below the class average or serious behavioral problems reported by teachers.

**Table 1A:** Characterization of the participants organized by gender and school grade.

| School grade | Gender Female | Gender Male | Total of students |
|---|---|---|---|
| First | 12 | 13 | 25 |
| Second | 9 | 6 | 15 |
| Third | 8 | 5 | 13 |
| Fourth | 6 | 4 | 10 |
| Fifth | 9 | 6 | 15 |
| **Total** | **44** | **34** | **78** |

**Table 1B:** Characterization of research participants organized by school grade.

| School grade | Class A | Class B | Class C | Class D | Total of students |
|---|---|---|---|---|---|
| First | 7 | 6 | 7 | 5 | 25 |
| Second | 5 | 5 | 5 | 0 | 15 |
| Third | 7 | 6 | 0 | 0 | 13 |
| Fourth | 5 | 3 | 2 | 0 | 10 |
| Fifth | 3 | 7 | 5 | 0 | 15 |

**Table 1C:** Characterization of research participants according to age by school grade

| School grade | Age | Minimum | Maximum |
|---|---|---|---|
| First | 6y8m | 6a 0m | 7a6m |
| Second | 7y6m | 6a11m | 8a2m |
| Third | 8y6m | 8a0m | 9a1m |
| Fourth | 9y2m | 8a0m | 9a11m |
| Fifth | 11y4m | 10a2m | 11a4m |

## 2.2 Instruments

### Computerized Attention Assessment Instruments

Initially, a fixation point (PF) was displayed on the center computer screen. After 700 ms, the point that was initially white changed to blue, indicating that the target (a 0.3-degree square superimposed on the central point) would come in one of 12 possible time intervals of 100; 400; 700; 1000; 1300; 1600; 1900; 2200; 2500; 2800; 3100 and 3400 ms (presented at 300 ms step of cue-target interval) (Figure 1). Each participant was instructed to fixate the gaze at the fixation point (FP), prepare to respond after FP changed color to blue and respond as quickly as possible to the occurrence of the target, pressing the space bar of the keyboard, measuring the reaction time (RT) in milliseconds.

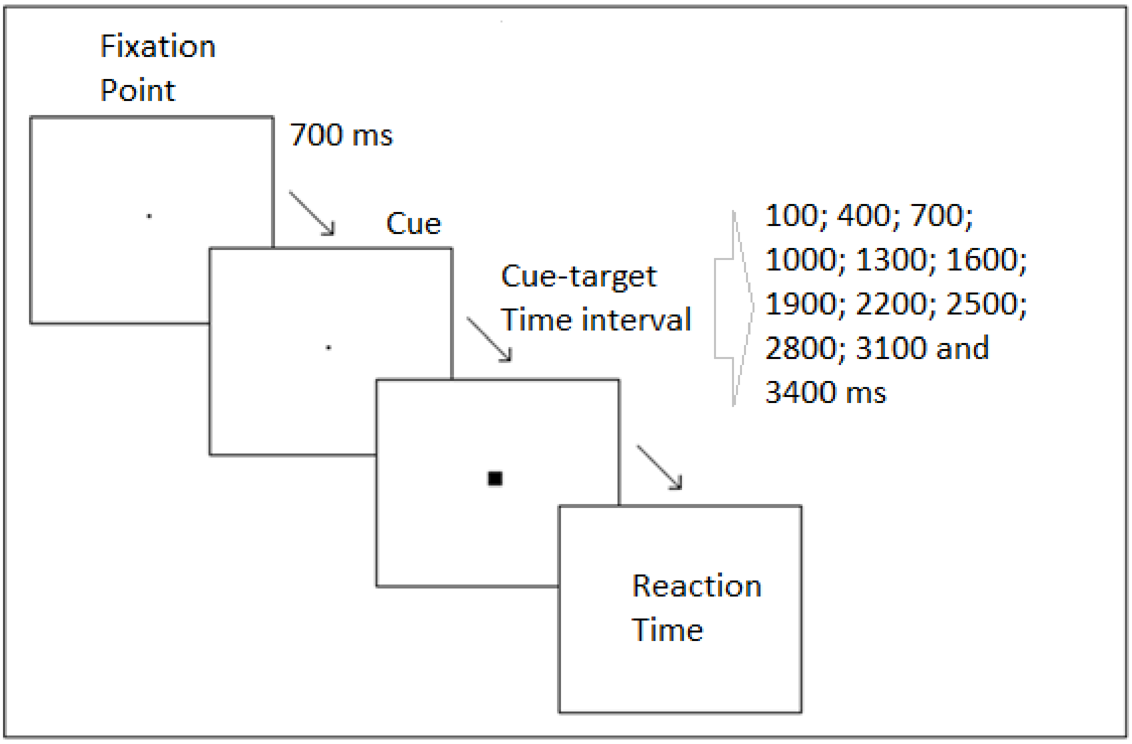


**Figure 1:** Temporal sequence of the stimulus presentation in experiment.

## 3. Results and discussion

The medians of the RT for each condition of this Experiment were submitted to a multifactorial ANOVA with repeated measures that comprised the following factors: Schooling (intergroup factor) with 5 levels (1st, 2nd, 3rd, 4th and 5th grade) and Cue-target time interval with (12 possible time intervals 100; 400; 700; 1000; 1300; 1600; 1900; 2200; 2500; 2800; 3100 and 3400 ms). The results can be seen in Table 1.

**Table 2:** Multifactor ANOVA results with repeated measures for the Experiment.

| Effect | SS | Degree of Freedom | MS | F | P |
|---|---|---|---|---|---|
| Schooling (intergroup factor) | 400E4 | 4 | 100E4 | 13,00 | <0,001* |
| Cue-target time interval | 184E4 | 11 | 168E3 | 26,71 | <0,001* |
| Schooling X Cue-target time interval | 212E3 | 44 | 4827,0 | 0,77 | 0,861 |

A significant effect was observed ($F(4, 73) = 13.001$, $p < 0.001$) for the intergroup factor "Schooling". In this manner, we observed a systematic decrease in the RT due to the increase in schooling.

In general, children in more advanced grades have lower RT compared to children of initial grades (Figure 1). It was also verified a significant effect (F (11, 803) = 26,708, p <0.001) for the Cue-target time interval Factor. Thusly, a systematic decrease of the RT is observed as a function of cue-target time interval increase (Figure 2).

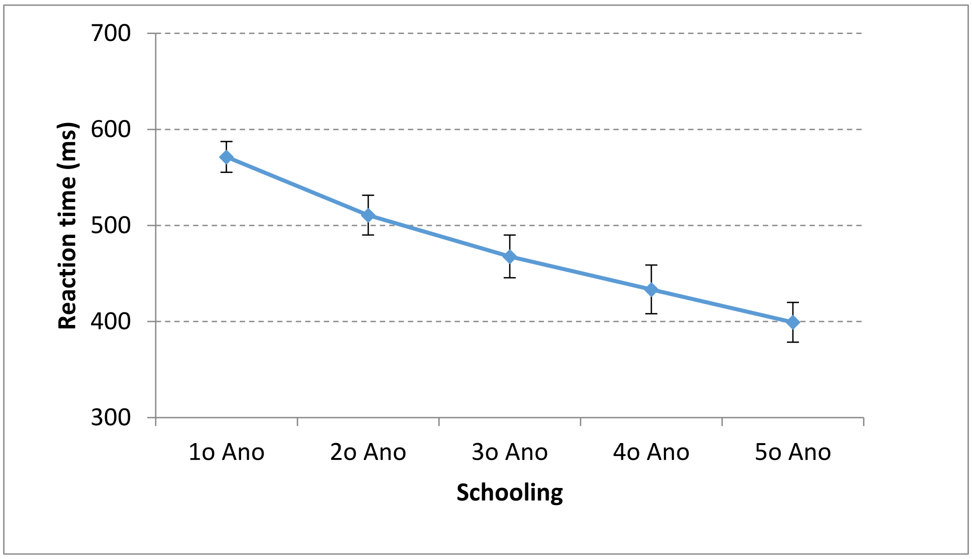


**Figure 1:** Reaction time in function of Schooling.

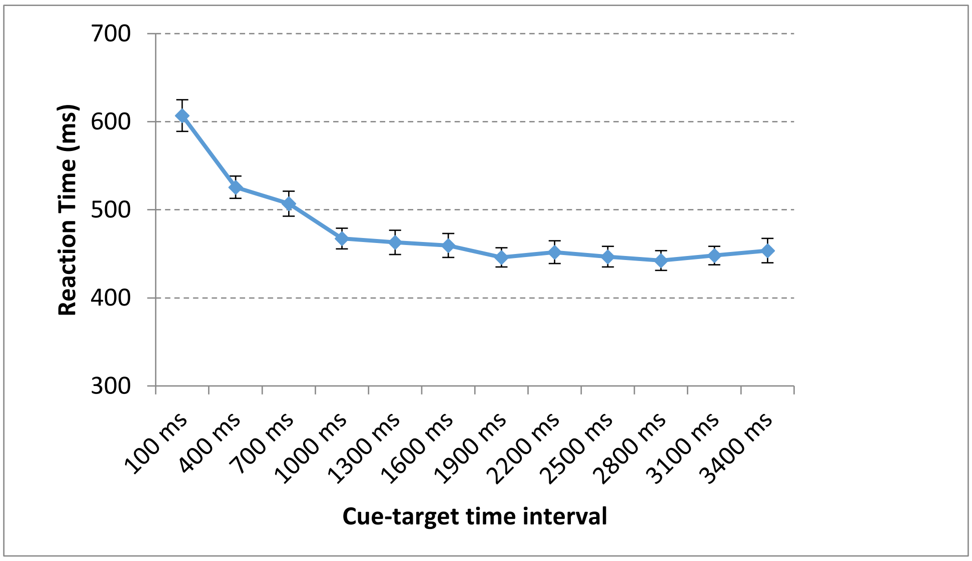


**Figure 2:** Reaction time in function of Cue-target time interval.

Figure 2 demonstrates a decrease in RT due to the continuous increase of the Cue-target time interval, however, when the results are separated according to the school grade (Figura 3), it is possible to observe some differences, even qualitatively, since this interaction is not statistically significant. The first observation is that initial series take more time to reach their lowest RT value. For example, the RT of the 1st and 2nd years reach their lowest value around the 1900 ms of interval. On the other hand, the students of the 5th grade get the lower RT earlier, on cue-target time interval of 400 ms. In addition, there is a tendency for RT in 1st and 2nd grade students increase at longer intervals, as if they could not sustain attention for so long, a characteristic not observed for the RT of students in the more advanced grades (3rd, 4th and 5th year).

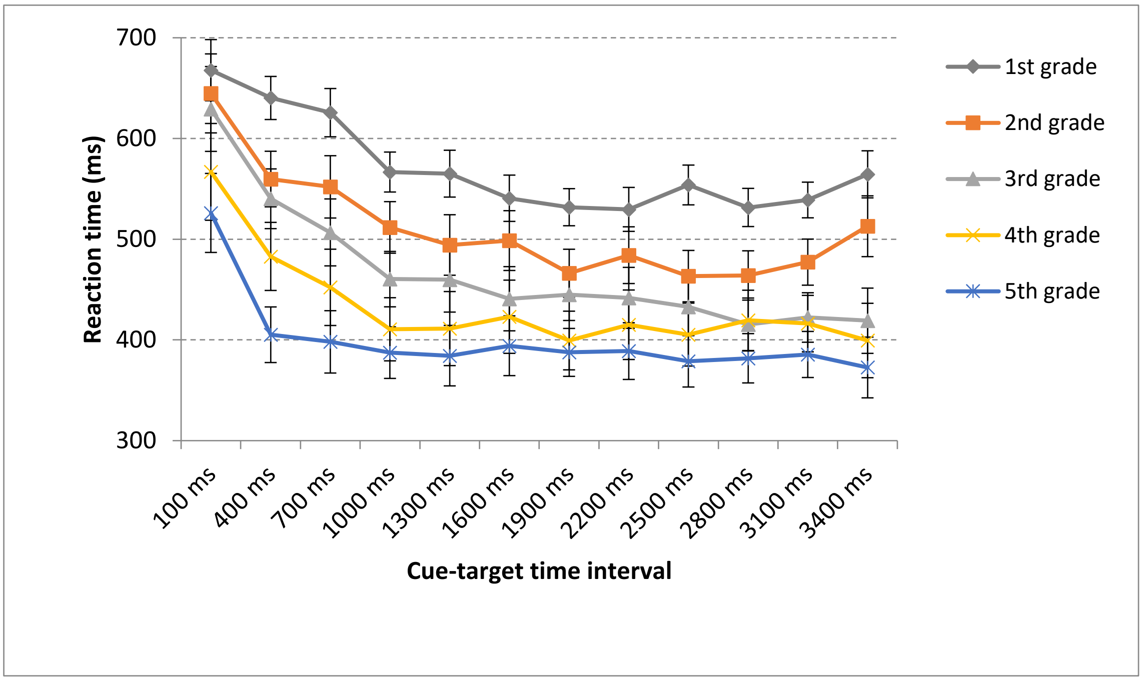


**Figure 3:** Reaction time in function of Cue-target time interval for different School grades.

Our results are consistent with Rueda et al. (2004) that evaluated orientation of attention, sustained attention and executive control. Participants were divided into four groups of 12 children aged 6 to 9 years. Participated in the experiment (6 boys and 6 girls). On a computer screen, children should focus on a fish. The participant should respond by pressing the left or right mouse button on which side the fish appears. In congruent trials the fish appeared in the same direction as the central fish, in incongruous trials the fish pointed in the opposite direction to the central fish. In neutral tests the central fish appeared alone. The results show that between 6 and 10 years of age the reaction time reduces and the number of errors decrease as the age increases.

Dye and Bavelier (2010) also describes that the maintenance of the sustained attention improves as a function of the school age. The difference of our result is that we demonstrated at what age and cue-target time interval the RT reaches its lowest value in relation to development. We also could compare temporal course of sustained attention in relation to different ages. These differences could be related to the nervous system maturation that during childhood development contribute to the effectiveness increases of cognitive processes and behavioral control. Consequently, the children's attention-orientation and maintenance skills improve as they grow up (Carreiro et al., 2015, Lellis et al., 2013). According to Betts et al. (2006), sustained attention has traditionally been assessed through long-term tasks, such as of signal identification tasks that usually results in a gradual decrease in performance over time. They also suggested that sustained attention develops during childhood, in age group of 5 to 9 years and then a functional adaptation can occur, improving sustained attention at 12 years. Our work corroborates the results from Betts et al., (2006) that age is a factor associated with improved performance of sustained attention.

## 4. Conclusion

When we analyze the series of reaction times, we verify that younger children have more difficulty maintaining sustained attention for longer. The reaction time of 1st and 2nd year children decreases as the interval increases. However, there is also for younger children a tendency to increase the RT in larger intervals, which was not observed for children of the 3rd, 4th and 5th school grades, that keeps shorter RT even for longer cue-target time interval.

## 5. Acknowledgement

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