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Motor timing deficits in children with Attention-Deficit/Hyperactivity disorder

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Children with Attention-Deficit/Hyperactivity Disorder (ADHD) are thought to have fundamental deficits in the allocation of attention for information processing. Furthermore, it is believed that these children possess a fundamental difficulty in motoric timing, an assertion that has been explored recently in adults and children. In the present study we extend this recent work by fully exploring the classic Wing and Kristofferson (1973) analysis of timing with typically developing children ($n = 24$) and children with ADHD ($n = 27$). We provide clear evidence that not only do children with ADHD have an overall timing deficit, they also time less consistently when using a similar strategy to typically developing children. The use of the Wing and Kristofferson approach to timing, we argue, will result in the discovery of robust ADHD-related timing differences across a variety of situations.

1. Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is characterized by a persistent pattern of developmentally inappropriate levels of inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2000). The high rates of heritability for ADHD suggest a genetic contribution, leading to investigations of cognitive endophenotypes in ADHD (Castellanos & Tannock, 2002; DiMaio, Grizenko, & Joober, 2003; Faraone & Doyle, 2001). However, the search for an elementary,

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behaviorally identifiable marker of ADHD that is not part of the symptomatology used in the DSM-IV definition has been elusive.

Past attempts to identify cognitive endophenotypes have almost exclusively focused on dysfunctions in the prefrontal cortex, namely executive functioning. In explicating these dysfunctions, however, both past theoretical and empirical work (for a review see Barkley (1997), and recent work by Rommelse and colleagues (Rommelse et al., 2008), suggest an endophenotypic component in ADHD related to time estimation and production. Individuals with ADHD and their non-affected siblings exhibited motor timing deficits compared to participants from families with no formally diagnosed or suspected ADHD behaviors or symptoms. Other studies, however, have failed to show differences in time estimation when comparing children with and without ADHD (see Toplak, Dockstader, & Tannock (2006) for a review).

Luman et al. (2009) examined timing variance of children with ADHD as well as children with ADHD and Oppositional Defiant Disorder (ODD) in a 1000 millisecond (ms) timed interval tapping task. The notion that ADHD is primarily a difficulty in response inhibition (Barkley, 1997) was supported by the observation that children with ADHD and children with ADHD + ODD underestimated the 1000 ms interval compared to typically developing children. Furthermore, children with ADHD exhibited a much larger timing variance than typically developing children.

Valera et al. (2010) utilized a timed tapping task and demonstrated that along with increased timing variability of adults with ADHD compared to adults without ADHD, neuro-anatomical areas of the central nervous system such as the cerebellum and basal ganglia, known to be motor timing areas, showed less activity for adults with ADHD compared to adults without ADHD. This result provides initial evidence that a tapping timing task can be used to capture fundamental neurological differences in ADHD.

Valera et al. (2010) and Luman et al. (2009) employed the most widely used and useful analytical model of time-keeping by Wing and Kristofferson (1973). However, in both studies, there was not a detailed analysis of what might be called Wing and Kristofferson behavior. For example, Luman et al. (2009) did not compute the classic motor and clock variances. Furthermore, Valera et al. did not report whether participants obeyed the fundamental assumptions of the Wing and Kristofferson model. Thus, in the current study, we examined timing in children with ADHD within the timing framework of Wing and Kristofferson. Furthermore, we fully explored how child participants with and without ADHD produce temporal intervals in a tapping task when the interval time series obeys the Wing and Kristofferson assumptions, compared to not obeying these assumptions.

In the Wing and Kristofferson (1973) model, it is assumed that timing is open-loop; participants are not basing the production of the next interval upon evaluating the duration of the previous interval(s). Wing and Kristofferson show how the variance of the time series can be decomposed into two additive components, the variance attributed to a central time-keeping process (clock), and the variance attributed to an implementation process (motor variance). Motor variance is computed from the covariance of adjacent intervals, termed the lag one covariance. The model computations require that the lag one covariance be negative. Furthermore, the lag one autocorrelation must be bounded between 0.0 and $-.05$. In other words, a long interval is followed by a short interval and vice versa, and the covariance cannot be greater than half of the total variance. Once the motor variance is calculated, the clock variance can be estimated by subtracting twice the implementation variance from the total variance.

One caveat is in order. The interval time series might drift from the prescribed rate. This “drift” increases the total variance and of course reduces the negativity of the lag one covariance. Thus, a time series is first detrended, on a trial by trial basis, to remove this unwanted source of variance and then the total detrended variance is partitioned into clock and implementation (motor) components (Keele, Pokorny, Corcos, & Ivry, 1985; Wing & Kristofferson, 1973).

If a time series of intervals is not consistent with the Wing and Kristofferson (1973) model, then time keeping might not be attributable to an open-loop central clock-like timing process (see Zelaznik, Spencer, & Ivry, 2008). In the present study we examined timing behavior across groups when the Wing and Kristofferson model was obeyed and not obeyed, respectively. By examining how timing precision differs for children with ADHD compared to children without ADHD in these conditions, we are able to examine various sources of timing precision.