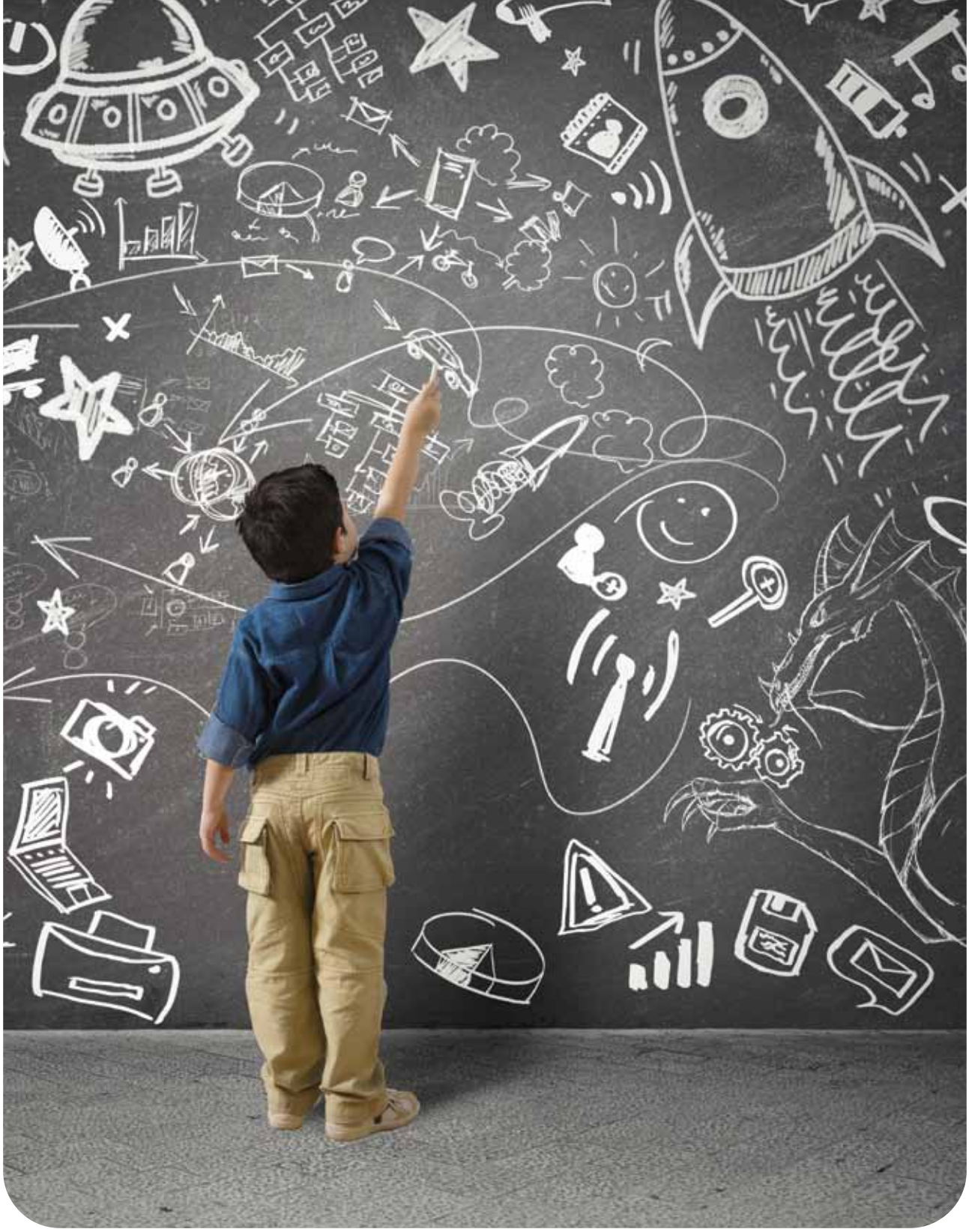

DID YOU SEE THE DISTRACTOR?
A MOXO CONTRIBUTION TO ADHD DETECTION

moxo

DISTRACTIBILITY IN ADHD

Increased vulnerability to distraction is a key feature of Attention-Deficit Hyperactivity Disorder (ADHD) and is included in the DSM-V criteria of the disorder (APA, 2013).
In contrast to hyperactivity, distractibility symptoms often persist into adulthood and contribute to interpersonal, social, family, academic, and work-related difficulties (Eakin et al., 2004; Biederman et al., 2006). Thus, identifying distractibility in ADHD patients and clarifying the distractibility features for individual patients can have significant clinical and diagnostic value.

The failure of existing studies to consistently show that ADHD patients are more sensitive to distractors than their non-affected peers (Huang-Pollock et al., 2006; Mason et al., 2005) has led some researchers to question whether selective attention is a core deficit in ADHD or whether attentional problems are secondary to deficits of alertness (Huang-Pollock et al., 2005) or other executive processes such as inhibition (Barkley, 1997).

One of the challenges in measuring distractibility during traditional ADHD assessments is that neurocognitive tasks are typically administered in laboratory conditions and are therefore limited in their ability to simulate the sensory context experienced by ADHD patients in everyday life (Pelham et al., 2011; Rapport et al., 2000). Specifically, nearly all Continuous Performance Tests (CPTs) are free of meaningful distractions which impact the cognitive performance of children with ADHD (APA, 2013). Another limitation is that most CPTs involve competition of potential responses in which there is a need to inhibit a response to irrelevant stimuli. This paradigm has been criticized for its low ecological validity (Blakeman, 2000) because in everyday life, individuals are required to ignore a stimulus that is external to the task and not conflicting with task demands (e.g., a child doing schoolwork while someone talks in the next room). These limitations may explain the loose association between CPT performance and behavioral measures of inattention and hyperactivity, such as those reported by parents and teachers in symptoms rating scales (McGee et al., 2000; Weis and Totten, 2004).

MEASURING DISTRACTIBILITY USING THE MOXO-CPT

The MOXO-CPT (Neuro Tech Solutions Ltd) is a standardized computerized test designed to identify ADHD-related behavior (Berger & Goldzweig, 2010). As in other CPTs, the MOXO task requires a participant to sustain attention over a continuous stream of stimuli and to respond to a pre-specified target. However, the MOXO paradigm also includes intentionally distracting visual and auditory stimuli which appear during specific phases of the test and are typical in their content to items in everyday life. As distractors external to the task (i.e., they do not conflict directly with task demands), they provide a context for measuring a patient's susceptibility to irrelevant periodic stimuli in the environment rather than ongoing background stimuli or distractors that are part of the cognitive task itself (Van Mourik et al., 2007).

In both child and adult versions of the MOXO Test, distractors can be exclusively visual, exclusively auditory, or multi-modal. In addition, there are two levels of distraction intensity: low-level distraction, where one distracting stimulus appears at a time, and high distraction intensity, where two distracting stimuli appear simultaneously. A number of studies have been conducted to test the use of this paradigm in different populations.

DISTRACTIBILITY IN CHILDREN

A study conducted with 663 children ages 7-12 years (345 with diagnosed ADHD and 318 controls) used the MOXO Test in order to examine the effect of the distractors on performance of ADHD and control subjects. This study used the rate of omission errors as an indication of attention difficulty. Results showed that while children with ADHD were negatively impacted (i.e., made more omission errors in the presence of all types of distractors), the performance of control subjects was affected only by the most intensive distractors – the combination of visual and auditory stimuli. This result underscores the relative susceptibility of ADHD patients to environmental distraction (Cassuto et al., 2013).

DISTRACTIBILITY IN ADOLESCENTS

Another study used the teen/adult version of the MOXO Test in order to investigate differences between distractibility in adolescents with ADHD and their unaffected peers as controls. This study included 176 adolescents ages 13-18 years (133 with ADHD and 43 controls). Results of this study showed that adolescents with ADHD produced significantly more omission errors in the presence of pure visual distractors and the combination of visual and auditory distractors than in no-distractor conditions. In contrast, distracting stimuli had no effect on MOXO performance of healthy control adolescents. Receiver Operating Characteristic (ROC) analysis further demonstrated that independent of modality, the inclusion of distractors in MOXO significantly improved the sensitivity and specificity of the test. These results support the concept that ADHD is indeed marked by high distractibility and that, like their younger counterparts, teenagers with ADHD have difficulty sustaining attention in the presence of irrelevant environmental stimuli (Berger & Cassuto, 2014).

HOW IS DISTRACTIBILITY ASSOCIATED WITH MATURATION?

It is commonly argued that ADHD symptoms are associated with maturational delay that gradually diminishes during adolescence in a majority of patients (Faraone et al., 2006). These pediatric populations with inhibitory deficits such as ADHD are characterized by reduced volume (Batty et al., 2010) and activity (Casey et al., 2011) in fronto-basal brain networks.

To examine the functional impact of this phenomenon in the context of distractibility, a cross-sectional study with children ages 6-11 compared the MOXO performance of six age groups of children with ADHD (N = 559) compared to unaffected peers (N = 365) (Berger et al., 2013). This comparison revealed that despite improvement across childhood, children with ADHD continued to demonstrate impairments as compared to normal controls. Specifically, attentional performance of ADHD children matched that of normal controls 1-3 years younger, with an effect most prominent in older children.

In addition, a separate analysis of MOXO performance of children ages 7-18 revealed that children and adolescents with ADHD were more readily distracted than their typically developing peers (Slobodin et al., 2015). Although distractibility diminished with advancing age in control adolescents, those with ADHD continued to be distracted in a way that resembled younger controls. Therefore, this study demonstrated that despite age-related improvement in attentional function in both groups, distractibility tended to diminish in non-ADHD adolescents, whereas subjects with ADHD were still sensitive to distractors even in late adolescence. These findings suggest that although some ADHD deficits can be explained by a developmental delay that improves over time, increased distractibility, does not show a clear developmental trajectory. Based on this finding, the distractibility results provided by the MOXO test may serve as a valuable criterion for identifying and tracking aspects of functional impairment among ADHD patients that are not apparent from traditional CPTs.

IMPROVED PERFORMANCE IN THE PRESENCE OF DISTRACTORS

Results of these studies consistently show that as a group, individuals with ADHD are negatively affected by the presence of distractors. However, literature and anecdotal reports on opposing findings, in which patients with ADHD showed improved cognitive ability in the presence of distractors have also been published (Uno et al., 2006; van Mourik et al., 2007). This diversity of responses may be attributable to the type of distractors used. While studies such as those of Uno et al and Mourik et al (ibid) have utilized neutral stimuli (neutral tone/letter) for distraction, the MOXO distractor stimuli are specifically designed to mimic distracting sensory input typically found in an everyday environment. Since individuals with ADHD have increased difficulty filtering meaningful distractors (Blakeman, 2000), they may fail to inhibit responses to relevant stimuli rather than to the neutral information used in other studies. By specifying this condition as well as providing baseline epochs which do not include distractors, the MOXO Test allows for clinician insight into the effects of salient distractors which more-closely model real-world attentional challenges.

SUMMARY

Traditional Continuous Performance Tests used to evaluate attention have been viewed as lacking ecological validity and clinical utility due in part to the absence of external distractors. Furthermore, recent attempts to include distractors CPT paradigms have been limited by the inclusion of non-salient or task-competitive stimuli.

The MOXO test has been designed to include salient stimuli that are independent of the core task with the goal of identifying distractibility as well as improving overall sensitivity and specificity of attentional results. In support of this, studies have demonstrated that children and adolescents with ADHD are more susceptible than age-matched controls to salient distractors. Furthermore, research using MOXO has also indicated that the developmental trajectories of attention and distractibility may be distinct from each other in teens with ADHD, suggesting that measures of attention alone may not be sufficient for predicting functional disability in adolescent ADHD.

REFERENCES

American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. Fifth Edition. Arlington, VA: American Psychiatric Press Inc.; 2013.

Barkley RA. Behavioral Inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychol Bull.* 1997;121:65–94.

Batty MJ, Liddle EB, Pitiot A, et al. Cortical gray matter in attention-deficit/hyperactivity disorder: a structural magnetic resonance imaging study. *J Am Acad Child Adolesc Psychiatry*. 2010; 49:229-3.

Berger I, Cassuto H. The effect of environmental distractors incorporation into a CPT on sustained attention and ADHD diagnosis among adolescents. *J Neurosci Methods*. 2014;222:62-8.

Berger I, Goldzweig G. Objective measures of attention-deficit/hyperactivity disorder – a pilot study. *Isrl Med Assoc J.* 2010; 12: 531-5.

Berger I, Slobodin O, Aboud M, Melamed J, Cassuto H. Maturational delay in ADHD: evidence from CPT. *Front Hum Neurosci.* 2013; 25 doi: 10.3389/fnhum.2013.00691

Biederman J, Faraone SV, Spencer TJ, et al. Functional impairments in adults with self-reports of diagnosed ADHD: a controlled study of 1001 adults in the community. *J Clin Psychiatry.* 2006;67:524–40.

Blakeman RS. ADHD and distractibility: the role of distractor appeal. *Diss Abstr Int B Sci.* 2000; 61, 517

Casey BJ, Somerville LH, Gotlib IH, et al. Behavioral and neural correlates of delay of gratification 40 years later. *Proc Natl Acad Sci USA*. 2011; 108: 14998–15003.

Cassuto H, Ben-Simon A, Berger I. Using environmental distractors in the diagnosis of ADHD. *Front Hum Neurosci.* 2013; 7: 805.

Eakin L, Minde K, Hechtman L, et al. The marital and family functioning of adults with ADHD and their spouses. *J Atten Disord.* 2004;8:1–10.

Faraone SV, Biederman J, Mick E. Decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychol Med.*2006; 36:159-65.

Huang-Pollock CL, Nigg JT, Carr TH. Deficient attention is hard to find: applying the perceptual load model of selective attention to attention deficit hyperactivity disorder subtypes. *J Child Psychol Psychiatry.* 2005;46:1211–18.

Huang-Pollock CL, Nigg JT, Halperin JM. Single dissociation findings of ADHD deficits in vigilance but not anterior or posterior attention systems. *Neuropsychology.* 2006;20:420–429.

Mason DJ, Humphreys GW, Kent L. Insights into the control of attentional set in ADHD using the attentional blink paradigm. *J Child Psychol Psychiatry.* 2005;46:1345–53.

McGee R, Brodeur D, Symons D, Andrade B, Fahie C. Time perception: does it distinguish ADHD and RD children in a clinical sample. *J Abnorm Child.* 2004; 32:481–90.

Pelham WE, Waschbusch D, Hoza B, et al. Music and video as distractors for boys with ADHD in the classroom: comparison with controls, individual differences, and medication effects. *J Abnorm Child Psychol.* 2011; 39: 1085–98

Rapport MD, Chung KM, Shore G, Denney CB, Isaacs P. Upgrading the science and technology of assessment and diagnosis: laboratory and clinic-based assessment of children with ADHD. *J Clin. Child Psychol.* 2000; 29: 555–68.

Slobodin O, Cassuto H, Berger I. Age-Related Changes in Distractibility: Developmental Trajectory of Sustained Attention in ADHD. *J Atten Disord.* 2015. pii: 1087054715575066.

Uno M, Abe J, Sawai C, et al. Effect of additional auditory and visual stimuli on continuous performance test (noise-generated CPT) in AD/HD children—usefulness of noise-generated CPT. *Brain Dev.*2006; 28: 162–9.

van Mourik R, Oosterlaan J, Heslenfeld DJ, Konig CE, Sergeant JA. When distraction is not distracting: a behavioral and ERP study on distraction in ADHD. *Clin Neurophysiol.* 2007; 118: 1855–65.

Weis R, Totten SJ. Ecological validity of the Conners' Continuous Performance Test II in a school-based sample. *J Psychoeduc Assess.* 2004; 22: 47–61