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Beating Their Chests: University Students With ADHD Demonstrate Greater Attentional Abilities on an Inattentional Blindness Paradigm

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Objective: Adults diagnosed with attentional deficit disorder (ADHD) are easily distracted in many tasks. Yet ADHD performance on inattentional blindness (IB) tasks has not been examined. Such investigation may aid in discriminating between 3 ADHD models: the neurological model, the perceptual load theory, and the "hunter versus farmer" hypothesis. ***Method:*** Distractibility was assessed in ADHD and non-ADHD college students using the MOXO task that involves detection of a single attended stimulus that repeatedly appears in the same place and in the well-known IB "gorilla" video which involves tracking of a stimulus moving at a fast pace in a dynamic, complex manner. ***Results:*** ADHD college students showed increased distractibility in the MOXO task. By contrast, they performed better than controls in the attended channel of the IB task, while they were also better at noticing the unattended stimuli and thus exhibiting little-to-no inattentional blindness. ***Conclusions:*** As no attentional tradeoffs were evident in the IB task, it appears that the results are most consistent with the "hunter versus farmer" hypothesis, which postulates that ADHD individuals have an alternative cognitive style which is less equipped to deal with detection of repeated stimuli while comprising advantages in the tracking of stimuli moving in a fast dynamic manner.

Keywords: attentional deficit hyperactivity disorder, ADHD, attention, inattentional blindness, hunter versus farmer hypothesis, distractors

A recent, well-publicized court case concerned a policeman (Officer Conley) who, while focusing on chasing a suspect, was "blind" to the beating of a colleague (Michael Cox) who he ran right past. He was subsequently convicted of perjury and obstruction of justice. In an empirical reenactment of the chase, 40% of subjects similarly failed to detect the staged "beating" (Chabris, Weinberger, Fontaine, & Simons, 2011).

While the officer's behavior horrified laymen, cognitive psychologists have known about this phenomenon of inattentional blindness (IB) for years. To the best of our knowledge, IB tasks have not been examined with adults diagnosed with attention deficit hyperactive disorder (ADHD). In addition to real world implications, assessing IB in subjects with ADHD may help to distinguish between three different theoretical accounts.

IB was defined by Mack and Rock (1998) as a failure to notice salient and foveated stimuli due to attention being engaged elsewhere. IB is a normal phenomenon occurring in people without cognitive deficits of any kind (Neisser, 1967). Perhaps the most famous IB task is the "gorilla" video (e.g., Simons & Chabris, 1999; Simons, 2010a), in which participants monitor ball passing in one of two teams, and approximately 50% of them were blind to a foveated "gorilla" walking across the court, standing still and beating its chest, and exiting (Simons & Chabris, 1999; Memmert, 2006).

The recent DSM-V (APA, 2013) treats ADHD as a single diagnostic category with different subtypes. ADHD diagnosis requires a persistent pattern of inattention symptoms (e.g., easily distracted, difficulty sustaining attention, forgetful) and/or hyperactive/impulsive symptoms (e.g., "on the go," interrupts, fidgets/squirms in seat). ADHD prevalence for children tends to be 4–18%; for example, it is 10% in the United States. (Faraone, Sergeant, Gillberg, & Beiderman, 2003) and 12% in Israel (Cohen et al., 2013). Recent reports suggest that ADHD symptoms (Das, Cherbuin, Easteal, & Anstey, 2014) and prevalence (e.g., 5% in the United States, Kessler et al., 2006) may decrease with age. Nonetheless, difficulties in adult ADHD individuals may be severe and are typically manifest in academia, employment, organization, and time management (Kessler et al., 2006). ADHD adults may also experience other difficulties such as anxiety and depression (Michielsen et al., 2013).

Several studies reported that ADHD individuals are more distracted than non-AHDH individuals. For example, in response to

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competition tasks, target processing is better when flanked by compatible versus incompatible distractors (Brodeur, & Pond, 2001; Jonkman et al., 2000). Response time was slower even when accuracy remained unaffected, (e.g., Geurts, Luman, & van Meel, 2008). However, in several other studies, ADHD individuals were comparable to non-ADHD controls (e.g., Huang-Pollock, Carr, & Nigg, 2002). Suggested approaches to this apparent discrepancy have been to propose that ADHD individuals are impaired relative to non-ADHD only with meaningful (Forster, Robertson, Jennings, Asherson, & Lavie, 2014) or emotional distractors (López-Martín, Albert, Fernández-Jaén, Carretié, 2013).

Although ADHD symptomatology is widely recognized, the underlying theoretical interpretation is disputed. One may discern three theoretical approaches. First, the neurological model conceptualizes ADHD as named, a *disorder/deficit*, whereby the inattention, impulsivity/hyperactivity or both, are viewed as a global distractibility impairment (DSM-V, 2013). This model is based on the hypothesis that altered dopaminergic function plays a pivotal role by failing to modulate nondopaminergic (primarily glutamate and gamma amino-butyric acid) signal transmissions appropriately. Hypo-functioning mesolimbic, mesocortical, and nigrostriatal dopamine branches together can give rise to delay aversion, development of hyperactivity, impulsivity, deficient sustained attention, increased behavioral variability, and disinhibition (Sagvolden, Johansen, Aase, & Russell, 2005). This model predicts global distractibility on all tasks for ADHD subjects relative to controls. Accordingly, cognitive–behavioral treatments (CBT; Knouse & Safren, 2010) and/or pharmacological agents (Wilens, Morrison, & Prince, 2011) are utilized in the “treatment” of the disorder.

The second model emerges from the perceptual Load Theory (e.g., Lavie, 2010). Load Theory states that focused selective attention (on task-relevant rather than irrelevant information) depends not only on goal-directed cognitive control but also on the perceptual load (amount of potentially task-relevant information) of a given task. While full top-down cognitive control ability is necessary for the active maintenance of the current task priorities (including prioritization of relevant over irrelevant stimuli), this alone is insufficient to achieve exclusive focus on relevant items. In tasks of low perceptual load, spare capacity left over from the processing of task-relevant attended stimuli will “spill over” resulting in the perception of distractor stimuli thereby interfering with the attended stream. It is only when the perceptual load of the task is high enough to exhaust perceptual capacity that distractor perception—and their intrusions into awareness—will be prevented (Remington, Cartwright-Finch, & Lavie, 2014). It was recently demonstrated that ADHD individuals were distracted by flankers only when the attended target had a low perceptual load but not under a high load, where their performance was no different from non-ADHD controls (Forster et al., 2014). As opposed to the neurological model, which views the entire dopamine reward network as faulty, the perceptual load model focuses mainly on distractibility and limits it to cognitive conditions, that is, a disorder manifest only when distractibility is high (low load). However when all resources are taxed, similar to controls, individuals with ADHD are not distracted.

The third ADHD model is Hartmann’s sociological/anthropological theory, wherein ADHD is described as a *hunter in a farming society* (Hartmann & Ratey, 1995). This theory views ADHD individuals as expert “hunters” who are prepared for action and are able to track complex and moving targets while taking in the entire environment (Hartmann, 1993). In contrast, this view categorizes the modern world as a “farmer’s” society, wherein advanced planning is cherished and focusing on one thing at a time is rewarded. From a young age, children in modern society are instructed to block out the multitude stimuli in a classroom and focus only on the teacher. By contrast, in a hunter-gatherer society when, for example, one chases after a rabbit for lunch, it is advantageous to also notice that one is being stalked by a hungry cheetah. As suggested by Hartmann, the ability to notice a non-target stimulus that may lead to distraction might be a desired trait to ensure survival of the hunter.

Accordingly, the very attributes that render ADHD individuals good “hunters” (e.g., constant monitoring of environment, flexibility, being able to throw themselves into a chase on a moment’s notice), are less compatible with modern, daily demands of the “farmer society.” Support for this theory has been observed in genetic evidence (Arcos-Burgos & Acosta, 2007). This model predicts impaired ADHD performance only on nonhunter tasks, where participants focus on a repeated stimulus as opposed to the tracking of a fast-moving stimulus, where ADHD individuals should be superior to non-ADHD.

All three models thus agree that ADHD individuals should perform significantly worse on farmer-type tasks where participants have to focus on a single, stationary, low-load target in the presence of a distractor. Indeed, it is just such tasks, such as the variety of continuous performance tasks (CPT), which are typically used to diagnose ADHD.

However, these models critically differ, with regard to the IB “gorilla” task. The classic model treats ADHD as a global impairment and if ADHD adults do notice the “gorilla,” it would likely be at the expense of counting passes. Due to the high perceptual load involved, the perceptual load theory would predict that ADHD and non-ADHD adults perform similarly. According to the “hunter” hypothesis, because this IB task is a “hunter” task, ADHD individuals should be better at both counting passes and at noticing the unattended distractors; for example, “gorilla.” Thus, in addition to the potential real-world ramifications, examining IB in ADHD might also serve to discern between the aforementioned three models.

Method

Participants

Fourteen ADHD subjects (age: 24.07 $\pm$ 1.9) and 18 matched controls (age: 23.38 $\pm$ 2.45), participated in this study in exchange for course credit. Participants were first-year Bar Ilan University students from social science programs who were recruited by signs posted in the social science buildings. All subjects had normal or corrected-to-normal vision. Exclusion criteria for both the ADHD and non-ADHD groups included diagnosed learning disabilities, history of neurological disorders, head injuries, diagnosed neurological impairment, and psychiatric disorders or medication (other than prescribed ADHD medication). In addition, individuals who had previously seen the IB video were excluded. All non-ADHD students reported no history of ADHD. The study was approved by the Institutional

Review Board (IRB) at Bar Ilan University's Interdisciplinary Department of Social Sciences and all participants provided written informed consent.

For inclusion in the ADHD group, subjects had to bring (a) a diagnostic report that included a *DSM–IV*-based questionnaire; (b) a neurological assessment including a CPT test (e.g., TOVAH test) and; (c) a prescription in their name for methylphenidate. Furthermore, all ADHD subjects were required to show that their diagnosis was recognized by the university's testing center entitling them to academic assistance (e.g., additional exam time). The university's diagnostic procedure is more conservative than the ADHD testing administered to the general public in Israel such that approximately a fifth of the ADHD students who apply to the program are rejected. ADHD participants were tested after 24 hr without medication.

Stimuli and Procedure

Two tasks were administered to each subject: a low perceptual load CPT task and a high perceptual load IB task. For the IB task, participants were seated in a quiet room, 75 cm from a computer monitor on which they viewed a video (Simons, 2010a; Simons, 2010b; see Figure 1). Distance and head stability were maintained using a chinrest and forehead bar. The video showed two teams (three black-clothed and three white-clothed) who were passing a basketball among their own team while moving around each other in a dynamic, fast-paced manner. We employed the "difficult version" (Simons & Chabris, 1999) wherein subjects were instructed to count the number of bounce passes, aerial passes, and total passes of the white-team while ignoring the black team. Three events of note occurred during the course of the video: (a) A "gorilla" entered the circle of players, beat his chest, and walked out, (b) One of the black-clothed players exited the scene, (c) The color of a background curtain changed from red to orange. After watching the movie, the subjects were questioned about both attended and unattended channels. Questions pertaining to the attended stream related to passes of the white team such as total number of passes, aerial passes, and number of bounce passes. Questions pertaining to the nonattended stream were: (a) "Did you notice anything unusual"? (b) "Did you see anything aside from the players"? (c) "Did you notice the "gorilla" walking across the display"? (d) "Did anything happen to the curtain"? (e) "Did you notice a player exiting the court"? We focused primarily on responses to the gorilla, player exiting, and the curtain color change, where "no" responses were taken to indicate "blindness." Importantly, responses were consistent, such that everyone (both ADHD and controls) who noticed something unusual noticed the gorilla and vice versa.

All subjects also performed the low perceptual load MOXO-CPT (Berger & Cassuto, 2014), as the ("farmer") comparison task. The MOXO-CPT is an 18.2-min test that includes visual and auditory distractor stimuli. It is composed of eight blocks (136.5 s, 59 trials each). In each trial, a card was presented as an attended target, and participants' task was to respond only to a certain card. Target was presented for 500, 1,000, or 4,000 ms, followed by a "void" period of the same duration. The stimulus remained on the screen for the full duration irrespective of response.

Target and nontarget stimuli were presented sequentially in the middle of a computer screen and participants were instructed to respond as quickly as possible to target stimuli by pressing the space bar once, and only once. Participants were also instructed not to respond to any other stimuli except for the exact target card, and not to press any other key but the space bar. Three types of distractions were presented: (a) visual distractors (e.g., animated

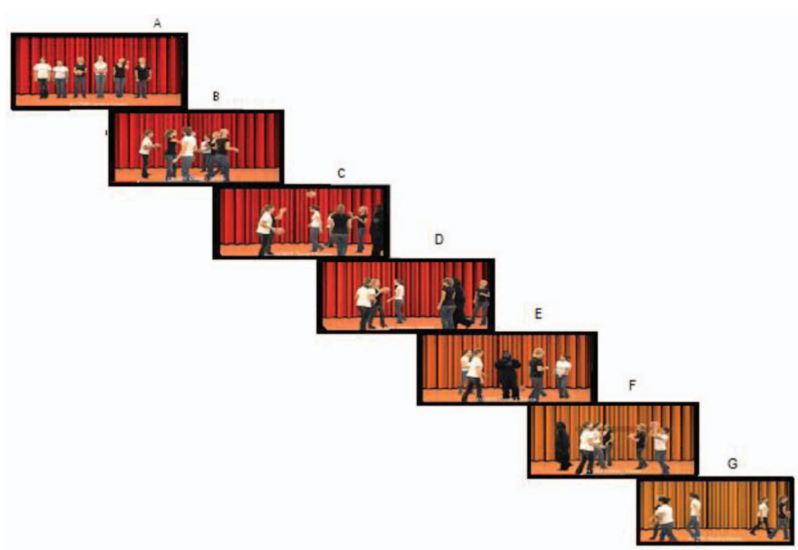

Figure 1. Selected still frames from video (Simons, 2010b). (A) The six players from the two teams prior to commencing passing, (B) Both teams are moving around and passing their own ball to their team members. (C) "Gorilla" enters from right. (D) Player from black team eases backward off the court while the "gorilla" walks to the center. (E) "Gorilla" stands in center and beats chest. Note change in curtain color. (F) "Gorilla" walks off. (G) Team members finish and disperse. See the online article for the color version of this figure.

barking dog); (b) auditory distractors (e.g., barking sound); and (c) a combination of both (e.g., animated barking dog with the sound of barking). Visual distractors appeared at one of four spatial locations on the sides of the screen: down, up, left or right. Overall, eight different distractors were included, each of them could appear as pure visual, pure auditory or as a combination of them.

The different MOXO-CPT blocks were characterized by different distractor levels. Blocks 1 and 8 did not include any distractors, Blocks 2 and 3 contained pure visual distractors, Blocks 4 and 5 contained pure auditory distractors and Blocks 6 and 7 contained a combination of visual and auditory distractors. Distractor onset was not synchronized with target onset and could be presented during the void period as well. Distractors were presented for 8 s, with a fixed interval of 0.5 s between two distractors.

The MOXO-CPT assesses attention along four criteria, (a) Attention: number of correct responses to target not bound by any time frame. (b) Timing: number of correct responses only while target is on screen. (c) Impulsivity: number of impulsive commissions performed in initial response to a nontarget stimulus. (d) Hyperactivity, remaining commission errors not counted as impulsivity, for example, multiple spacebar presses (as opposed to initial) or random key pressing.

Results

Inattentional Blindness Task

ADHD adults detected the unattended stimuli, that is, the entering "gorilla" (13/14 vs. 4/18, $\chi^2 = 15.77$, $p < .001$) and the exiting player (10/14 vs. 1/18, $\chi^2 = 15.14$, $p < .001$) significantly more often than controls. Not only was there no attentional trade off, ADHD students were actually better in their overall pass counting relative to non-ADHD students, $t(29) = 1.76$, $p < .05$, $d = .61$, one-tailed (Figure 2a). Although there was no difference between groups in aerial pass counting, ADHD subjects were also significantly better in counting the six bounce passes, $t(29) = 2.26$, $p < .05$, $d = .79$. In fact the count of bounce passes by the ADHD group was no different than the correct answer ($t < 1$), however non-ADHD controls provided a significantly lower count of bounce passes than the accurate number, $t(17) = 3.35$, $p < .01$, $d = .83$. The color changing of the background curtain was not detected by any subject.

MOXO Task

Subjects with ADHD performed at lower levels than controls on all four MOXO dimensions. These differences between ADHD and non-ADHD groups were significant in Attention (all hits), $t(29) = 2.56$, $p < .05$, $d = .91$, and Hyperactivity (commission errors), $t(29) = 2.51$, $p < .05$, $d = .89$. The differences in Impulsivity (impulsive commissions in initial response) and Timing (hits during target display) were not significant, see Figure 2b. One non-ADHD participant was removed due to outlier performance; this removal did not change results.

Discussion

The IB results demonstrate that ADHD adults can perform a demanding task while simultaneously processing unattended stimuli at no apparent cost. This advantage did not result from an attentional trade-off, as the ADHD subjects were significantly better than controls in two of the three attended tasks (total passes, bounce passes). These results hint at the existence of attentional advantages for those with ADHD.

These results can help disambiguate the three theoretical accounts. Although impaired MOXO performance was predicted by all three ADHD models, performance on the IB task can differentiate between the aforementioned models. The high percentage of ADHD subjects noticing both the "gorilla" and the exiting player could have been predicted both by the neurological and the "hunter" models. However, taken together with the lack of attentional trade-off, the overall result pattern seems compatible only with Hartmann's sociological-anthropological theory. As "hunters," ADHD adults have attentional advantages, in that they can simultaneously perceive information from attended channels while also doing so from unattended channels.

While a central difference between the MOXO and the IB tasks is tracking motion, a hallmark of "hunter" tasks (Hartmann, 1993), there are several additional differences. First, the cognitive load seems higher in the IB task where the simultaneous tracking of both aerial and bounce passes is required, as opposed to the MOXO where a single target is presented (see also Cartwright-Finch & Lavie, 2007

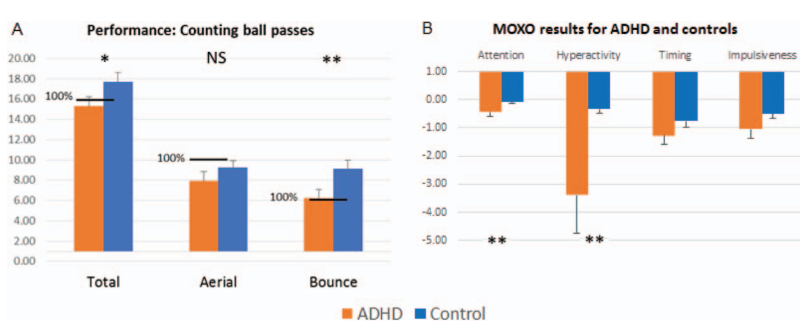

Figure 2. IB and MOXO results for ADHD and Control groups. Panel A. Average (+*SE*) results on all four MOXO dimensions for ADHD and Control subjects. Panel B. Average (+*SE*) performance of both ADHD and controls on the attended task of monitoring Total passes (16), Aerial passes (10) and Bounce passes (6). Significance at .05 *one-tailed, **two tail. See the online article for the color version of this figure.

for a similar claim). Differing from perceptual load that stems from perceptual properties of the stimulus, cognitive load relates to the taxing of working memory. The more taxed it is, the less resources remain for processing other cognitive tasks (Baddeley, 1974). The current IB task also requires constant updating to accommodate new input (Morris & Jones, 1990). Updating one of the two representations of aerial and bounce passes, that change independently, is more taxing than updating a single representation (Kessler & Meiran, 2006) and definitely more taxing than the MOXO, which does not even require updating at all.

A second difference is that in the MOXO task participants' distraction was inferred *implicitly* by interference to the attended stream, as opposed to the IB task where noticing the "gorilla" was an *explicit*, conscious response. Implicit paradigms (e.g., MOXO) focus on how well irrelevant albeit expected stimuli can be ignored whereas explicit paradigms focus on the probability of noticing an unexpected but potentially relevant stimulus (Simons, 2000). Implicit attentional capture may exist in the absence of explicit attentional capture (Moore & Egeth, 1997). Perhaps ADHD individuals are better than controls in monitoring an environment for unexpected albeit potentially relevant information typical of explicit attentional capture while being less attuned to irrelevant distractors information.

A third difference between the MOXO and the current IB task relates to how "ecological" the stimuli were. In the MOXO, the target stimulus was an animated picture of a card while in the IB task the attended channel is a real world situation, that is, a video of a real ball being passed by real people. Given that previous research indicates differences on ADHD performance between ecological and nonecological stimuli (see Forster et al., 2014), this issue may be important.

These differences of cognitive load, explicit versus implicit, and ecological level, may all be compatible with the "hunter" hypothesis. A "hunter" task may involve a higher *cognitive load* such as keeping two objects in working memory, explicitly noticing a relevant albeit unexpected stimulus which was not initially attended, and ecological stimuli. To better ascertain the role of each factor, future studies could compare between explicit IB tasks that vary in terms of motion, cognitive load of the primary task, and updating. This should be examined using both more and less ecological stimuli.

There may be alternative explanation for the current results. It has recently been shown that ADHD performance may be task dependent (Bioulac et al., 2014), for example, when a task is not framed as a test but as a game, ADHD performance is enhanced. The current IB task may be reminiscent more of a game than a test while the MOXO most probably reminds the ADHD participants of diagnostic tests that they have encountered.

The current results indicate that ADHD may not be a global impairment, rather it may be more accurate to describe it as an alternative cognitive style comprising disadvantages, which may be manifest in "farming" tasks (e.g., MOXO), along with advantages which might be manifest in "hunting" tasks. Efficacy of therapeutic interventions, such as CBT (e.g., Knouse & Safren, 2010) or pharmacological agents (Wilens et al., 2011) in decreasing distractibility is standardly assessed to the extent by which ADHD function converts to "normal." While such treatments are valuable as they enhance functioning, it should be noted that if ADHD is not a global deficit it may not require a global intervention. Instead, ADHD performance could be facilitated in situations where they might encounter difficulties along with finding ways to express their strengths.

The current results are also important in terms of the potential daily implications of IB. For example, in a recent study (Drew, Võ, & Wolfe, 2013) radiologists were given CT lung scans for nodules where a picture of a dancing "gorilla" 48 times larger than an average nodule appeared. Over 80% of these expert detectors failed to notice the "gorilla." As detecting a stationary nodule may not comprise a "hunter" task, we cannot speculate how ADHD radiologist would fare. Yet based on the current results, one may speculate that an ADHD policeman chasing after a fugitive would *likely* notice her fellow policewoman being beaten.

There are several potential limitations to our study. This is a single study that employed only two tasks that may differ along several dimensions. Thus, future research is required both for replication and to precisely determine the role of each dimension. Furthermore, the ADHD diagnosis of our subjects relied on historical data. The lack of diagnosis testing as part of the study is relevant both to the ADHD group, where independent nonhistorical verification of ADHD was lacking, and the control group, who might have possibly included some ADHD subjects who were never diagnosed. Although this concern is mitigated somewhat by the apparent confirmation from the MOXO task that distinguished between the groups, administration of the MOXO was not for diagnostic purposes and thus it might have been preferable to administer an independent diagnostic measure. Similarly, exclusion of participants with self-reported disorders such as learning disabilities or psychiatric disorders may likewise be a limitation for the same reason, namely that the sample might have included undiagnosed participants. Furthermore, given the comorbidity between learning disabilities and ADHD as well as psychiatric disorders and ADHD, not including these participants may limit the generalizability of the results. We also note that while our sample size was sufficient to show significant results, a larger study is certainly warranted. We also acknowledge that our evaluation of "hunter" versus "farming" tasks might be confounded with other factors. Finally, the issue of ADHD is more salient in children, thus it is important to evaluate the relative degree of IB in both ADHD and non-ADHD children across various ages.

In conclusion, while ADHD participants were more distracted on the MOXO CPT task than non-ADHD, they "saw the unseen" and demonstrated little intentional blindness. Critically, their noticing of the unattended "gorilla" did not distract them from processing the attended stream, in which they were also significantly better. The full result pattern is compatible with the "hunter versus farmer" hypothesis. These results stimulate many questions both about the nature of ADHD and their attentional capabilities.

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