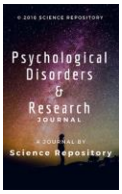
Differences in measurements of hyperactivity between objective testing using infrared motion analysis (QbTest) and behavioural rating scales when comparing problems in alerting functions and response inhibition during the clinical assessment of ADHD



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Case Report

Differences in measurements of hyperactivity between objective testing using infrared motion analysis (QbTest) and behavioural rating scales when comparing problems in alerting functions and response inhibition during the clinical assessment of ADHD. A case study

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ABSTRACT

Introduction: Little is known how problems in alerting functions or response inhibition affect objective infrared activity measurements during a continuous performance test (QbTest) despite an increasing use of these tests for the clinical assessment of ADHD. Difficulties in alerting functions and response inhibition are both associated with the presence of behavioural features in all three core domains of ADHD, i.e. inattention, impulsivity and hyperactivity. We hypothesized that objective infrared activity measurements during CPT and behavioural ratings for hyperactivity from a commonly used questionnaire for ADHD (Conners rating scale) would be raised for both alerting functions and response inhibition.
Method: 951 sequential referrals completed a QbTest and parent and teacher Conners rating scales followed by a clinical assessment with a CAMHS clinician. Two groups, one with exclusive difficulties in alerting functions (inattention) and the other with exclusive difficulties in response inhibition (impulsive) resulting from the QbTest performance were extracted from the pool and activity measurements, rating scales and diagnostic outcome were compared.
Results: Contrary to our hypothesis, only the group with difficulties in alerting functions (inattentive) showed significantly raised activity measurements during CPT. However, both groups had raised scores for hyperactivity in the behavioural rating scales. A higher number of cases with difficulties in alerting functions (79.6%) were assigned a diagnosis of ADHD compared to the group with exclusively difficulties in response inhibition (61.8%).
Discussion: A cautious evaluation of activity measurements during the QbTest with full consideration of the interplay between naturalistic and laboratory environmental effects on motor activity is recommended

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Introduction

Infrared motion analysis combined with a continuous performance test (CPT) are commercially available investigations for the clinical assessment of ADHD. These instruments, such as the QbTest, (https://www.qbtech.com/qbtest.html) provide objective measurements of the three core signs of ADHD: inattention, hyperactivity and impulsivity. Their utility in clinical practice is gathering widespread interest due to potential improvements in assessment, targeting of interventions and outcomes [1-3]. Recently the FDA approved the use of the Qb test as an aid to the "clinical assessment of ADHD" and "in the evaluation of treatment interventions". Little is known how the results from automated testing compare with rating scales, history taking and a face to face clinical examination for the purpose of a diagnostic assessment in clinical practice.

CPT has been extensively used with regards to impairments related to vigilance and alerting function and response inhibition. Impairment in vigilance and alerting function usually marked by a slow reaction time and variable response times during CPT is considered an important component of ADHD and its associated core symptoms [4, 5]. Deficits in inhibitory control functions have also been implicated with ADHD combined type [6-8]. Considerable research from laboratory measures has supported a deficit in response inhibition in these children [9]. Selective difficulties with alerting functions or response inhibition produce distinct neurocognitive profiles during CPT with an alerting function/inattentive profile solely showing a slow reaction time, increased reaction time variation and increased omission errors and a response inhibition/impulsive profile demonstrating purely commission errors.

Diagnosis of ADHD in clinical practice relies on a psychiatric interview and information from two or more settings (e.g. parental report and teacher report). The reports from different settings are often supplemented by the use of a questionnaire designed to assess ADHD, such as the Conners Ratings Scales. In this study, we hypothesized that the activity measurements during the QbTest would be raised for both, the alerting function/inattention group and the response inhibition/impulsive group matched with raised scores for hyperactivity in the Conners rating scales.

Method

Participants

951 sequential referrals completed a QbTest and parent and teacher Conners rating scales followed by a clinical assessment with the CAMHS clinician. Furthermore, a school observation was undertaken when additional information was required for the completion of the diagnostic process. Reports of developmental assessments by paediatricians and educational psychologists were also provided when indicated or requested when considered essential for the clinical assessment. This process is part of our standard practice for all referrals made to our ADHD pathway service. The source of new assessments reflects the broad spectrum of referrals from primary care, (i.e. GP's, paediatricians, schools), and internal CAMHS referrals. The age range was 6-18 years.We excluded referrals with learning disability, on psychotropic medication for psychiatric disorders or with a medical history of epilepsy controlled with anti-epileptic medication, cases with incomplete Conners rating scales, invalid QbTests or artefacts during the QbTest and cases that presented with excessive sleep deprivation prior to the QbTest.

QbTest

The QbTest is a continuous performance test (CPT) combined with a simultaneous high-resolution motion tracking system together providing data on the core signs of ADHD, that is, inattention, hyperactivity and impulsivity (www.qbtech.se/products/qbtest). The test can be used in children (6-12 years) and in adolescents and adults (12-60 years). The CPT differs in cognitive demand between the children version (Go/No-Go paradigm) and the adolescent/adult version (unconditional identical pair paradigm) of the test. After watching a demonstration video, the test examiner asks the participant to explain the task and complete a practice to allow the examiner to check whether the participant's responses indicated a proper understanding of the task.

The movements of the participant are recorded with by an infrared camera tracking a reflective marker attached to a headband that the participant wears while performing the test. The infrared camera is placed about 1 m away from the participant, who is sitting in front of a computer screen. In order to evaluate a given test person's QbTest performance, a representative control group is needed as comparison. Therefore, normative data have been gathered from several different cohorts comprising 1307 individuals between 6 and 60 years with an even age and gender distribution [10]. The parameters in the QbTest fit a non-symmetric (skewed) density rather than a symmetric Gaussian density. Therefore, a Gamma density function is used to model QbTest parameters. The q-score expresses the probability determined by the Gamma function in terms of standard deviation (z-score) of the more common Gaussian density.

Profiles

Two distinct profiles resulting from the CPT performance were extracted from the pool of 951 test results. The profiles were distinguished by their contrasting characteristics with one profile highlighting exclusive difficulties in alerting functions (AF/INA group) and the other profile demonstrating exclusive difficulties with response inhibition (RI/IMP group). Difficulties in alerting functions are heavily weighted in the QbTest inattention factor (QbINA; see below) and difficulties in response inhibition are heavily weighted in the QbTest impulsivity factor (QbIMP; see below)

The threshold for inclusion and exclusion was based on q-score standard deviations from the following Qb-Test parameters:

Q-score (standard deviation)	AF/INA Group	RI/IMP Group
Reaction time	>= 2	<1
Reaction time variation	>1	<1
Omission error	>1	<1
Commission error	<1	>1

Reaction time is the average elapsed time from stimulus presentation to button press. The Reaction time is measured only when a correct button press is registered. Reaction time reflects speed of processing and execution and support generally an arousal and alerting deficit. To capture the importance of a potential deficit in alerting or arousal within the inattention group, the threshold for the reaction time was increased to 2 standard deviations.
Reaction time variation is the standard deviation of the Reaction time. This measure reflects the moment to moment fluctuation in reaction time performance and reflects difficulty sustaining attention. Slower scores in reaction time and reaction time variation support a deficit in e.g. state regulation, alerting or arousal functions [10].

An omission error occurs when no response is registered when the stimulus was a target, i.e. the button was not pressed when it should have been. Omission errors represent an inability to remain focused on the task. Findings of increased errors of omission have been related to selective attention and deficient arousal [10]. A commission error occurs when a response is registered when the stimulus was a non-target, i.e. the button is pressed when it should not have been pressed. Commission errors are a measure of impulsive behaviour and believed to result from the anticipatory or incomplete processing of the stimulus [10].

Comparison

Between the AF/INA and RI/IMP group, weighted scores for activity (QbACT factor), inattention (QbINA factor) and impulsivity (QbIMP factor) were compared as well as the following activity parameters : (a) Time active, which reflects the percentage of time the subject has moved more than 1 cm/s; (b) Distance, which reflects the distance travelled by the reflective headband marker and is measured in meters; (c) Area, measured as the surface covered by the headband reflector during the test and is presented in square centimeters; (d) Total number of microevents, small movements of the reflective marker that occur when a position changes since the last microevent is greater than 1 mm.

Conners rating scales

The Conners 3 parent and teacher rating scales, were used to include behaviour ratings from home and school and compare scores for inattention, hyperactivity/impulsivity, learning problems/executive functioning, defiance/aggression and peer relations between the two groups [12].

Statistical analysis

Multivariate analysis of variance (MANOVA), univariate analysis, Fisher's exact test and Pearson's correlation were carried out using the statistical package SPSS, version 21. Variables were correlated with chronological age. Therefore, chronological age was used as a covariate for the subsequent analyses.

Results

Out of the 951 new assessments between 2013-2016, 49 cases (5%) met criteria for the AF/INA group and 34 cases (3.6%) met criteria for the RI/IMP group. The average age in the AF/INA group was 10.25 years (SD 2.67) compared to 8.77 years in the RI/IMP group (SD 3.06), which is statistically significant (t (81) = 2.34, p=0.022). Thus, amongst clinic referrals the RI/IMP profile is found in younger children in comparison with the AF/IMP profile. Due to the significant difference in age between the impulsive and inattentive group and statistically significant correlation between age and some of the variables, age was controlled for in the analyses reported here using multivariate analyses of variance (MANOVA). In the AF/INA group, there was higher proportion of girls (17; 35%) in comparison to the RI/IMP group (5; 15%), reaching statistical significance (Fisher's exact test p= 0.048).

The co-morbid conditions documented at the time of the referral included Autism Spectrum Disorder [AF/INA group: 11 (22%); RI/IMP group 6 (17%)], Anxiety Disorder [AF/INA group: 2 (4%); RI/IMP group: 3 (8%)], Oppositional Defiant Disorder [AF/INA group: 7 (14%);RI/IMP group: 5 (14%)], Conduct Disorder (AF/INA group: 2 (4%); RI/IMP group: 1 (3%); Tourette's Syndrome [AF/INA group: 1 (2%);RI/IMP group : 1 (3%)] and Developmental Coordination Disorder [AF/INA group: 3 (6%); RI/IMP group: 2 (6%)].

QbTest Variables

An initial MANOVA of Qb factor scores (Activity- QbACT; Impulsivity – QbIMP and Inattentiveness – QbINA) with age as covariate and impulsive-inattentive as the independent variable showed that the multivariate F was significant (F (3,79) =204.98, p<0.001, partial $\eta 2$= 0.89). The univariate tests for group were all significant (QbACT F (1,81) = 17.88, p < 0.001, partial $\eta 2$ = 0.18; QbIMP F (1,81) = 107.80, p < 0.001, partial $\eta 2$ = 0.57; QbINA F (1,81) = 424.28, p < 0.001, partial $\eta 2$ = 0.84).

Reference to table 1 shows that the group effects are due to both higher scores in reaction time, reaction time variation, omission error and higher activity scores in the AF/INA group. The mean activity scores in the AF/INA group were abnormally high for the QbAct factor (q-score: 1.81) whereas in the RI/IMP group, mean activity scores were within the normal range (q-score: 0.99). A similar relationship holds for the QbINA factor. The QbIMP factor scores show the opposite pattern: the RI/IMP group score abnormally high (QbImp factor mean = 1.44), whereas the AF/INA group score in the normal range (QbImp factor mean = -0.17).
Next, a MANOVA for the Qb subtest scores was carried out in order to further identify group differences. There was a statistically significant multivariate difference for group (F (10,72) =66.27, p<0.001, partial $\eta 2$=0.90.

The group effects were seen on all the subscales: Time active F(1,81) = 24.52, p < 0.001, partial $\eta 2$ = 0.23); Distance F(1,81) = 19.02, p < 0.001, partial $\eta 2$ = 0.19); Area F(1,81) = 18.18, p < 0.001, partial $\eta 2$ = 0.19); Microevents F(1,81) = 19.13, p < 0.001, partial $\eta 2$ = 0.19); Omission error F(1,81) = 185.77, p < 0.001, partial $\eta 2$ = 0.70); Commission error F(1,81) = 155.23, p < 0.001, partial $\eta 2$ = 0.66); Reaction time (F(1,81) = 396.93, p < 0.001, partial $\eta 2$ = 0.83); Reaction time variation (F(1,81) = 234.22, p < 0.001, partial $\eta 2$ = 0.74). Unsurprisingly, the AF/INA group presented with exclusively high scores for the parameters associated with alerting function difficulties (reaction time, reaction time variation, omission error) and in contrast, the RI/IMP group presented exclusively high scores for the response inhibition parameter (commission error) – see table 1 for means of the subscales. Importantly, the AF/INA group show much higher activity scores than the RI/IMP group.

Table 1: Means (Standard deviations) of the QbTest factor scores and Qb test measures expressed as q scores for the AF/INA and RI/IMP groups.

Variable	Group	
	RI/IMP	**AF/INA**
Qb factor q scores		
QbACT**	0.99 (0.96)	1.81 (0.80)
QbIMP**	1.44 (0.64)	-0.17 (0.73)
QbINA**	-0.16 (0.69)	3.13 (0.73)
Qb subscale q scores		
Time active **	0.81 (0.85)	1.61 (0.61)
Distance **	0.95 (1.08)	1.92 (0.93)
Area **	1.04 (1.08)	1.99 (0.90)
Microevents **	0.96 (1.03)	1.87 (0.87)
Omission error**	0.06 (0.76)	2.08 (0.59)
Commission error **	1.62 (0.51)	-0.086 (0.67)
Reaction time **	-0.57 (0.75)	2.80 (0.76)
Reaction time variation **	0.024 (0.67)	2.71 (0.86)

** indicates that the difference between groups is significantly different at the 0.01 level or better according to the MANOVA analyses reported in the text.

Rating Scale Variables

The rating scale scores are shown in table 2. Two MANOVAs of respectively the teacher ratings scale score and the parent rating scale scores were carried out with Qbtest defined group as the independent variable and age as the covariate.

Table 2: Means (Standard Deviations) of the Conners scores reported by teachers and parents for the impulsive and inattentive groups

Variable	Group	
	RI/IMP	**AF/INA**
Teacher Conners Scale Scores		
Inattention	70.79 (11.13)	74.36 (12.62)
Hyperactivity/impulsivity	76.21 (14.12)	79.31 (13.64)
Learning problems/ executive functioning	65.00 (11.09)	66.53 (12.02)
Defiance/aggression	73.26 (16.47)	73.83 (18.63)
Peer relations	73.52 (15.25)	76.35 (15.95)
Parent Conners Scale Scores		
Inattention	84.71 (8.70)	82.35 (10.60)
Hyperactivity/impulsivity	85.45 (10.56)	83.60 (10.90)
Learning problems	68.32 (14.23)	71.37 (13.32)
Executive functioning	76.87 (11.84)	71.96 (12.39)
Defiance/aggression *	82.58 (11.51)	75.59 (16.14)
Peer relations	68.97 (17.89)	73.59(15.95)

*indicates that the difference between groups is significantly different p=0.04)

There was a marginally significant group effect ($F(6,66) = 2.29$, $p = 0.045$, partial $\eta^2 = 0.17$) for the parent ratings. Inspection of the univariate F values showed that there was a significant group effect on the parent rating of defiant aggression ($F(1,71) = 4.63$, $p = 0.04$, partial $\eta^2 = 0.06$). The RI/IMP group were rated as having more problems with defiant and aggressive behaviours than the AF/INA group. There was no statistically significant difference between the groups on teacher ratings ($F(5,72) = 0.48$, $p = 0.79$, partial $\eta^2 = 0.03$).

We also investigated the final diagnosis assigned in the clinical notes to the individuals in the two groups. The proportion assigned a diagnosis of ADHD was higher in the AF/INA group (79.6%) than in the RI/IMP group (61.8%) this difference is not statistically significant (Fisher's exact test = 0.086).

Discussion

The low occurrence of profiles with predominantly difficulties in alerting functions (5%) or response inhibition (3.6%) could either reflect the very selective criteria we applied in this case study to extract homogeneous profiles and to assess the impact of alerting functions and response inhibition features on activity levels, or it could also demonstrate that selective neuropsychological deficiencies are infrequent in a conventional clinic sample representative of a child and adolescent mental health service, despite there being considerable research from laboratory studies instating alerting functions and response inhibition as two main components of ADHD.

Against our hypothesis, activity measurements during the QbTest were only significantly raised for the AF/INA group and of normal range for the RI/IMP group. Our findings correspond with evidence that activity levels during objective measurements are primarily associated with basic attentional rather than inhibition processes [12, 13].

Characteristically slow reaction times and large reaction time variations are amongst impairment in alerting functions also associated with slower cognitive processing, deficient cognitive energetic resources and slower motor speed, and have been implicated as cognitive demand deficits resulting in increased motor activity which may reflect an attempt to increase cortical arousal [5, 14-19]. A study by Hartanto et al. found that in ADHD excessive motoric activity such as fidgeting during cognitive performance reflects efforts to modulate attention and alertness [20]. Thus, it is possible that in an attempt to maintain their attention during the test, participants in the AF/INA group began fidgeting and moving relatively more than their counterparts in the RI/IMP group.

On the other hand, there does not seem to be an association between raised impulsive responses during CPT (RI/IMP group) and a propensity to increased excess activity. The inhibitory deficiencies commonly related to response inhibition are deficient interference control, difficulty withholding a response in the presence of prepotent stimuli and delay aversion [21-24]. One explanation for the absence of raised activity could be that the Go/No Go paradigm used during the CPT places insufficient demands on the inhibition system to elicit a significant increase in activity [12]. However, a more rigorous experimental study by Alderson et al. manipulating the demands placed on behavioural inhibition in children with ADHD and comparing inhibition and noninhibition experimental tasks supported evidence that behavioural inhibition was not associated with increased activity, leading Alderson et al. to conclude that current and past findings raise the question about the role of behavioural inhibition in producing ADHD behavioural symptoms [12].

Although there is quantitatively a difference between the two groups, the high variance of activity in both groups suggests additional heterogeneity, pointing out to a more complex interplay with other factors that can influence activity other than those related to executive functions as described above, for example motor control (e.g. overflow movements) and motor timing difficulties, mechanical posture weakness, sensory modulation disorder and subcortical impairment [5, 25-28].

In accordance with the literature evidence, difficulties in alerting functions or response inhibition present with behavioural features in all three core domains of ADHD [5]. Similarly, the parent and teacher Conners ratings for inattention and hyperactivity/impulsivity in our study were raised in both groups and scores were not statistically different between the AF/INA and RI/IMP group. Interestingly, indirect associations were found, such as higher parent ratings for defiance/aggression in the RI/IMP group compared with research evidence pointing to a higher prevalence of defiant/aggressive behaviour in the hyperactive/impulsive presentation of ADHD, the significantly higher numbers of girls in the AF/INA group and a known lower male:female ratio in the predominantly inattentive presentation for ADHD [29, 30]. Furthermore, the differences in average age between the AF/INA and RI/IMP group is comparable with epidemiological data showing a younger age range in the predominantly impulsive/hyperactive ADHD presentation in comparison with an older age range in the predominantly inattentive ADHD presentation [30, 31].

Objective measurements are undertaken in specified laboratory setups required to identify the neurocognitive profiles. The common view to date is that computer-based measurements on their own have limited ecological validity [21, 32]. Considering the impact of the laboratory setup on behaviour, certain types of ADHD, normally regarded as prevalent independent of changing environmental or cognitive demands, may actually be more responsive to mitigating environmental factors than previously thought [33]. Thus, considering the Qbtest conditions with low perceptual load (few distractions) and support from a 1:1 test facilitator, children in the RI/IMP group appear able to sustain their attention during CPT but may find it more difficult in contrast to our test conditions in a large size classroom, limited 1:1 teaching support or a busy household where the amount of distractions and context changes are high. Similarly, children in the AF/INA group do not display impulsive behaviour during CPT, but may demonstrate a propensity for unfocused, careless and inaccurate behaviour (observed as impulsive behaviour) in a setting with high perceptual load.

There was a higher rate of children (17.8 %) in the RI/IMP group to have a diagnosis of ADHD ruled out in comparison with the AF/INA group. This difference did not quite reach statistical significance. Taking into account that during the QbTest, the activity as well as attention measurements were mainly normal in the RI/IMP group, a difficulty in one particular aspect of the test may possibly have been perceived as not sufficiently different to a child's typical performance and the clinician may have regarded other behavioural domains, such as defiance/aggression as more relevant [34]. However, we recommend a cautious evaluation of activity measurements during the QbTest with full consideration of the interplay between naturalistic and laboratory environmental effects on motor activity in a given child.

Limitations

The final numbers for analysis (AF/INA vs. RI/IMP) are modest given the multiple testing and a bigger sample for future analysis would strengthen the validity of the statistical results and reduce the possibility of a type 1 error. Grouping (AF/INA and RUI/IMP) was based on theoretical generalisation. Most of the clinical diagnoses made in both groups, were broadly documented as ADHD without further or consistent specification of the type of presentation, i.e. combined, predominantly inattentive or predominantly hyperactive/impulsive presentation.

Declaration of conflict of interest

The authors declare no conflict of interest

Ethical considerations

This case study is based on an audit of routine clinical practice. Informed consent was obtained prior to undertaking objective measurements with QbTest from the parents of participating children as well as the young person and their parents.

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