Brief Communication

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Attention, impulsivity and executive function scales and Quotient ADHD System properties: a correlation study

Escalas de atenção, impulsividade e função executiva e propriedades do Sistema Quotient ADHD: um estudo de correlação

Escalas de atención, impulsividad y función ejecutiva y propiedades del Sistema Quotient ADHD: un estudio de correlación

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ABSTRACT

Assessment and quantification of Attention, Hyperactivity and Impulsivity symptoms and losses it promotes to an individual is a challenging task. A computerized assessment tool, Quotient ADHD® System, intends to provide objective measurements of hyperactivity, inattention an impulsivity on an individual basis. In a sample of 64 adults, we correlated results of this tool with scores of self-report scales for ADHD symptoms, impulsiveness and executive functions. Significant Spearman's correlations ($p \leq .05$) were found between Quotient ADHD® scores and ADHD symptoms, impulsivity and executive function scores. Considering results obtained, we assume Quotient ADHD® might be a useful instrument to help evaluate inhibition control related to impulsiveness and inattention, suitable for detecting disorders with attention and impulsivity compromise.

Keywords: ADHD, attention, continuous performance test, executive functions, impulsivity, Quotient ADHD®

RESUMO

Avaliar e quantificar os sintomas de atenção, hiperatividade e impulsividade e os prejuízos que ela promove a um indivíduo é uma tarefa desafiadora. Uma ferramenta de avaliação computadorizada, Quotient ADHD® System, pretende fornecer medidas objetivas de hiperatividade, desatenção e impulsividade individualmente. Em uma amostra de 64 adultos, correlacionamos os resultados dessa ferramenta com pontuações de escalas de autorrelato para sintomas de TDAH, impulsividade e funções executivas. Correlações significativas de Spearman (p≤,05) foram encontradas entre os escores do Quotient ADHD® e os escores de sintomas de TDAH, impulsividade e sintomas de funções executivas. Considerando os resultados obtidos, assumimos que o Quotient ADHD® pode ser um instrumento útil para ajudar a avaliar o controle da inibição relacionada à impulsividade e desatenção, sendo adequado para detectar distúrbios com comprometimento da atenção e impulsividade.

Palavras-chave: TDAH, atenção, teste de desempenho contínuo, funções executivas, impulsividade, Quotient ADHD®

RESUMEN

La evaluación y cuantificación de los síntomas y pérdidas de atención, hiperactividad e impulsividad que provoca en un individuo es una tarea desafiante. Una herramienta de evaluación computarizada, Quotient ADHD® System, pretende proporcionar mediciones objetivas de hiperactividad, falta de atención e impulsividad de forma individual. En una muestra de 64 adultos, correlacionamos los resultados de esta herramienta con puntajes de escalas de autoinforme para síntomas de TDAH, impulsividad y funciones ejecutivas. Se encontraron correlaciones de Spearman significativas (p≤.05) entre las puntuaciones del Quotient ADHD® y las puntuaciones de los síntomas del TDAH, la impulsividad y los síntomas de las funciones ejecutivas. Teniendo en cuenta los resultados obtenidos, asumimos que Quotient ADHD® podría ser un instrumento útil para ayudar a evaluar el control de la inhibición relacionada con la impulsividad y la falta de atención, siendo adecuado para detectar trastornos con compromiso de la atención y la impulsividade.

Palabras clave: TDAH, atención, test de rendimiento continuo, funciones ejecutivas, impulsividad, Quotient ADHD®

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Introduction

Cognitive déficits are common symptoms in many psychiatric and neurological disorders [1, 2]. A correct evaluation of those symptoms is essential to characterize individual impact, evaluate potential outcomes and treatment efficiency. In most cases scales are answered by patient or caregiver and answers are quite subjective [3]. Specially for research purposes, there is a huge interest to have tasks able to inform in a consistent pattern about every individual.

Quotient ADHD® system (previously MMAT/ADHD™ System) is a computerized device intended to measure individual's ability to control motion, sustain attention and inhibit impulsivity, providing objective measurements of hyperactivity, inattention and impulsivity in Attention Deficit Hyperactivity Disorder (ADHD) patients [4, 5]. It is composed by a

"go / no go" style continuous performance task (CPT) coupled with infrared motion tracking systems (IRMTS) [4, 5].

Our goal was to compare measurements obtained with Quotient ADHD® portable model and scores of executive functions, impulsivity, and ADHD symptoms self-report scales in a Brazilian population sample.

Method

Participants

Sixty four healthy 20 to 46 year-old adults (46 women, 18 men; mean age = 28.9 ± 7.3 years), with 12.0 ± 2.1 years of formal education were recruited. All participants had normal or corrected-to-normal visual acuity in both eyes, no history of traumatic brain injury, epilepsy or self-reported psychiatric illness. A local ethics committee approved all procedures, and participants signed an informed consent after receiving full explanation of the study. All procedures performed were in accordance with ethical standards of institutional and national research committee (CAAE:12344813.0.0000.5149), and with 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Procedure

Participants were submitted to Quotient ADHD® assessment and then evaluated with Adult ADHD Self-Report Scale (ASRS-18) [6], Barratt Impulsiveness Scale (BIS-11) [7] and Barkeley Deficits in Executive Function Scale (BDEFS) [8].

Quotient

For this study Quotient ADHD® portable was used. Attention task consists of four different kinds of stars (four, five, eight and sixteen points) flashing for a fraction of a second on a background. Stars flash one each time randomly, with random intervals and positions on screen. Participant is instructed to press a button as fast as he can every time a star appears on screen, except for the four pointed star.

Results obtained from assessment is divided in: **(1)** *Scaled Scores*: three numerical values in 0 to 10 range summarizing magnitude of disturbance in motion (Motion Scaled Score), attention (Attention Scaled Score) and global performance (Global Scaled Score); **(2)** *Motion Analysis*: motion

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results obtained from IRMTS; **(3)** A*ttention Analysis*: results of CPT task and a classification of patient's response style for each block of attention task [2]. Scaled Scores are derived from Quotient's IRTMS and CPT variables and were not used in this study.

Quotient's Motion Analysis reports six variables measured by IRTMS. **(1)** *Immobility Duration*: average amount of time participant stay still; **(2)** *Movements*: number of positions change greater than 1mm; **(3)** *Displacement*: distance travelled by reference on participant's head; **(4)** *Area*: surface enclosed by reference's path; **(5)** *Spatial Complexity*: number reflecting movement style, i.e. lower values for linear movements, and higher values to more complex displacements; and **(6)** *Temporal Scaling*: number describing how movement happens in time, lower values meaning lack of movement while higher means incessant movement [2].

Attention Analysis reports: (1) *Accuracy*: percentage of correct responses based on commission and omission errors; **(2)** *Omission Errors*: percentage of targets missed; **(3)** *Commission Errors*: percentage of incorrect hits to non-targets; **(4)** *Latency*: average time to respond a target; **(5)** *Variability*: standard deviation of *Latency*; and **(6)** *C.O.V.* (Coefficient Of Variation): variability corrected for *Latency* [2].

Patient's response style breaks the 20 minutes attention task into 40 continuous 30 seconds blocks classified as attentive, impulsive, distracted, or disengaged. Number of Shifts is how many times patient changed its classification status; and Attentive, Impulsive, Distracted, and Disengaged are percentage of blocks classified accordingly. The classification criteria used by Quotient for the blocks are based on the methodology proposed by Teicher et al. [11].

A custom variable, *Attention Fragmentation Index* (AFI), was computed from patient's response style for each subject. AFI was calculated as $(A_T - A_M) / A_T$, where A_T is the number of blocks classified as attentive and A_M is the number of blocks in longest continuous attention block.

ASRS-18 is a scale listing symptoms of ADHD according to DSM-IV-TR criteria. *Hyperactivity/Impulsivity* and *Inattention* scores were obtained using methodology described in Kessler et al. [9]. This methodology was evaluated by Leite [6] who got better sensitivity and specificity for Brazilian population than usual approach.

BIS-11 is a questionnaire to assess personality/behavioral construct of impulsiveness [7]. Its scores were obtained using Vasconcelos et al. [10] two factor model obtained for Brazilian population, resulting in two scores: *Inhibition Control* and *Non-Planning*. BIS-11 was adapted for Brazilian population by Malloy-Diniz et al. [7].

BDEFS is a self-report questionnaire to evaluate daily deficits in executive functions (EF) in adults. There are five EF scores obtained from BDEFS, which evaluate: **(1)** *Self-Management to Time*: punctuality, time estimation, prioritization and planning ahead, **(2)** *Self-Organization/Problem Solving*: organization of ideas and ability to overcome obstacles to goals, **(3)** *Self-Restraint*: consequences of own actions, **(4)** *Self-Motivation*: sustain quality and output and postpone rewards, **(5)** *Self-Regulation of Emotions*: control one's own emotions. BDEFS also provides a *Total EF Summary Score* summarizing EF scores, an *EF Symptoms Count*, and *ADHD/EF Index* which suggests risk of ADHD and need of further evaluation [8].

Statistical Analysis

Statistical analysis was conducted using IBM SPSS Statistics v.22. Descriptive statistics [Table 1], Shapiro-Wilk's normality test and histograms were computed for all variables. Since most of variables didn't have normal distribution, non-parametric statistics were used. Spearman's correlation coefficients (r_S), their two-tailed significance tests (p), and coefficients of determination (r_S^2) were computed [Table 2]. All correlations with $p \leq .05$ were considered significant. Correlations were classified according to Cohen's [3] criteria.

Results

All significant correlations fell in $.247 \leq r_S \leq .380$ range, and had coefficients of determination in $.061 \leq r^2 \leq .144$ range [Table 2]. According to Cohen's effect size classification [11], all significant correlations can be classified as medium to large.

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Tabela 1. Performance of study participants on measures of attention, impulsivity, and behavioral scales

Instrument	Variable	Mean	SD	Min	Max
ASRS-18	Inattention	6.0	7.02	0	24
	Hyperactivity/Impulsivity	5.3	8.32	0	29
BIS-11	Inhibition control	38.9	7.20	23	61
	Lack of planning	21.7	4.46	12	30
BDEFS	Self-Management to Time	43.1	12.61	23	71
	Self-Organization / Problem Solving	43.8	12.4	25	82
	Self-Restraint	31.5	8.5	20	58
	Self-Motivation	19.2	5.97	12	36
	Self-Regulation of Emotions	23.9	6.99	13	46
	Total EF Summary Score	161.6	36.79	100	257
	ADHD-EF Index	19.8	5.25	12	33
	EF Symptoms Count	16.9	14.64	0	53
Quotient	Immobility (ms)	681.8	531.48	132	3096
	Movements	806.5	573.44	101	2682
	Displacement (m)	1.1	.98	.11	5.21
	Area (cm^2)	31.1	33.99	3	209
	Spatial Complexity	1.3	.23	1.053	2.161
	Temporal Scaling	.3	.22	.000	1.497
	Accuracy (%)	81.1	11.90	51.0	99.7
	Omission Errors (%)	.4	.57	.0	3.0
	Commission Errors (%)	37.3	23.69	.0	97.9
	Latency (ms)	455.3	66.88	322	655
	Variability (ms)	86.9	20.82	40	157
	C.O.V.	20.0	8.77	13	83
	Number of Shifts	18.7	5.60	2	30
	Attentive (%)	51.1	21.25	2.5	85.0
	Impulsive (%)	39.1	23.95	.0	97.5
	Distracted (%)	9.6	13.91	.0	87.5
	Disengaged (%)	.2	1.03	.0	7.5
	Attention Fragmentation Index	.7	.13	.0	.87

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Table 2. Spearman's Correlation Coefficient (r_s) and Coefficients of Determination (r_s^2).

			Motor Analysis (IRTMS)						Attention Analysis (CPT)											
			Imm	Mov	Disp	Area	SC	TS	Acc	Om	Com	Lat	Var	COV	NS	Att	Imp	Dis	Dsg	AFI
ASRS-18	Inattention	r_s	-.214	.189	.192	.232	-.160	.150	**-.317**	.044	**.313**	**-.250**	-.013	.245	.074	**-.380**	**.296**	-.061	-.091	-.040
		r_s^2	.046	.036	.037	.054	.026	.023	**.100**	.002	**.098**	**.063**	.000	.060	.005	**.144**	**.088**	.004	.008	.002
	Hyperactivity / Impulsivity	r_s	-.225	.177	.184	**.255**	-.172	.037	-.227	.046	.224	-.137	.041	.228	.101	**-.295**	.199	-.011	.085	.002
		r_s^2	.051	.031	.034	**.065**	.030	.001	.052	.002	.050	.019	.002	.052	.010	**.087**	.040	.000	.007	.000
BIS-11	Inhibition Control	r_s	-.186	.157	.187	**.289**	-.225	.154	**-.280**	.068	**.286**	-.070	.137	**.307**	.094	**-.330**	.200	.074	.052	.063
		r_s^2	.035	.025	.035	**.084**	.051	.024	**.078**	.005	**.082**	.005	.019	**.094**	.009	**.109**	.040	.005	.003	.004
	Lack of Planning	r_s	.106	-.156	-.152	-.105	.111	-.081	.043	.025	-.039	.028	-.045	-.082	-.230	.120	.004	-.141	**.253**	-.114
		r_s^2	.011	.024	.023	.011	.012	.007	.002	.001	.002	.001	.002	.007	.053	.014	.000	.020	**.064**	.013
BDEFS	Self Management to Time	r_s	-.079	.065	.079	.080	-.015	.081	**-.263**	-.094	**.267**	-.144	.011	.214	.084	**-.333**	.228	-.022	-.009	-.026
		r_s^2	.006	.004	.006	.006	.000	.007	**.069**	.009	**.071**	.021	.000	.046	.007	**.111**	.052	.000	.000	.001
	Self Organization Problem Solving	r_s	.071	-.057	-.063	-.056	.059	.041	-.032	-.023	.034	.095	.134	.114	-.022	-.093	.031	.144	-.018	-.152
		r_s^2	.005	.003	.004	.003	.003	.002	.001	.001	.001	.009	.018	.013	.000	.009	.001	.021	.000	.023
	Self Restraint	r_s	-.063	.085	.095	.135	-.077	.001	-.194	.049	.195	-.005	.055	.144	.061	**-.247**	.113	.038	.011	-.014
		r_s^2	.004	.007	.009	.018	.006	.000	.038	.002	.038	.000	.003	.021	.004	**.061**	.013	.001	.000	.000
	Self Motivation	r_s	-.061	.030	.041	.066	-.022	.146	-.092	-.163	.097	-.025	.018	.107	.069	-.171	.020	.139	.000	-.104
		r_s^2	.004	.001	.002	.004	.000	.021	.008	.027	.009	.001	.000	.011	.005	.029	.000	.019	.000	.011
	Self Regulation of Emotions	r_s	.107	-.076	-.079	-.125	.130	-.004	-.085	-.008	.083	.104	.128	.111	-.021	-.143	.113	.048	-.007	.019
		r_s^2	.011	.006	.006	.016	.017	.000	.007	.000	.007	.011	.016	.012	.000	.020	.013	.002	.000	.000
	Total EF Score	r_s	-.014	.024	.033	.035	.000	.089	-.179	-.054	.181	-.023	.087	.194	.073	**-.255**	.130	.102	-.007	-.067
		r_s^2	.000	.001	.001	.001	.000	.008	.032	.003	.033	.001	.008	.038	.005	**.065**	.017	.010	.000	.004
	ADHD-EF Index	r_s	-.020	.036	.046	.054	-.003	.059	-.225	-.089	.229	-.104	.013	.166	.098	**-.310**	.207	.029	-.088	.000
		r_s^2	.000	.001	.002	.003	.000	.003	.051	.008	.052	.011	.000	.028	.010	**.096**	.043	.001	.008	.000
	EF Symptom Count	r_s	-.108	.113	.122	.104	-.062	.138	-.203	-.086	.207	-.060	.074	.198	.058	**-.285**	.148	.090	-.023	-.104
		r_s^2	.012	.013	.015	.011	.004	.019	.041	.007	.043	.004	.005	.039	.003	**.081**	.022	.008	.001	.011

Notes: All correlations with $p \leq .05$ are highlighted. Imm = Immobility; Mov = Movements; Disp = Displacement; SC = Spatial complexity; TS = Temporal scaling; Acc = Accuracy; Om = Omission errors; Com = Commission errors; Var = Variability; COV = Coefficient of variation; NS = Number of shifts; Att = Attentive; Imp = Impulsive; Dist = Distracted; Dsg = Disengaged; AFI = Attention fragmentation index.

Motion Analysis (IRTMS)

The only Motion Analysis Quotient variable to attain significant correlation was *Area*. *Area* correlated with ASRS-18's *Hyperactivity/Impulsivity* score and with BIS-11's *Inhibition Control* score. Individuals with higher areas were those with less impulsivity control due to deficient inhibit control, showing more symptoms of hyperactivity/impulsivity. *Area* explained 6.5% of hyperactivity/impulsivity variation and 8.4% of inhibition control kind of impulsivity variation.

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Attention Analysis (CPT)

Amount of commission errors correlated significantly with ASRS-18's *Inattention*, BIS-11's *Inhibition Control*, and BDEFS' *Self-Management to Time*. Participants who committed more commission errors were those who displayed worse impulsivity control due to deficient inhibition control, showing more inattention symptoms and more inability to manage time.

Latency correlated with ARSR-18's *Inattention*. Participants with lowest reaction time were those with more inattention symptoms.

Finally, *C.O.V.* had significant correlation with BIS-11's *Inhibit Control*. Individuals with higher *C.O.V.* were those with worse impulsivity due to deficient inhibition control.

Percentage of attention correlated negatively with ASRS-18's scores, BIS-11 *Inhibition Control* and BDEFS' *Self-Management to Time*, *Self-Restraint*, *Total EF Summary Score*, *ADHD/EF Index*, and *EF Symptoms Count*. Percentage impulsive time correlated positively with ASRS-18's *Inattention* score. *Disengaged* time correlated positively with BIS-11's *Lack of Planning* score.

Discussion

This study founds association bewteen the Quotient ADHD System measures and some results obtained from Self-report scales. Higher inattention symptoms were observed in participants with more commission errors and shorter reaction times. These results align with some previous findings. For instance, inattention and commission errors have been linked to impulsivity based on behavioral symptoms described by parents [12].

In their study using Conner's CPT, Epstein et al. [4] inferred that both commission and omission errors should be regarded as measures of general ADHD symptomatology, rather than specific indicators of any one ADHD symptom domain. An analysis of the attention state of these individuals showed a moderate correlation with the profile assessed by scales. These correlation scores imply that Commission Errors and Latency could be reliable parameters for evaluating inattention and impulsivity.

Interestingly, the percentage of attention showed a negative correlation with ASRS-18 scores and with BDEFS metrics such as Self-Management to Time, Self-Restraint, Total EF Summary Score, ADHD/EF Index, and EF

Symptoms Count. Both scales are commonly used to gauge ADHD symptoms. Barkley and Murphy [14] argue that scales are more sensitive than cognitive tests in assessing the deficits of ADHD patients. Conversely, some studies have found no correlation between scales and test results [3]. Our findings deviate from these, and a primary reason might be the unique nature of the Quotient ADHD System, which is designed for higher ecological validity.

We discovered that the Inhibitory control derived from BIS-11 has a correlation with both attention and motor measures from the Quotient ADHD System. This aligns with the idea that inhibitory control encompasses motor and attentional components [13].

From a motor analysis perspective, individuals displaying more hyperactivity/impulsivity symptoms covered a more extensive area than their counterparts. Displacement, however, did not correlate with hyperactivity/impulsivity symptoms. The larger area covered was linked to the intensity of impulsivity symptoms. Both the number of commission errors and the variability in corrected latency were higher in these participants. These findings echo the results from studies by Malloy-Diniz et al. [7] and Amon Scarf [15].

Our study does have limitations to note. The sample size and lack of a clinical group restrict the broader applicability of our findings. Future research should consider more representative samples and incorporate clinical groups. Given our results, we propose that the Quotient ADHD System could be a valuable tool for assessing types of inattention and impulsivity related to inhibition control. It could provide insights into deficits in disorders marked by attention and impulsivity challenges.

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