



# Quotient ADHD System

Ou Zhang

Ph.D. Psychometrics

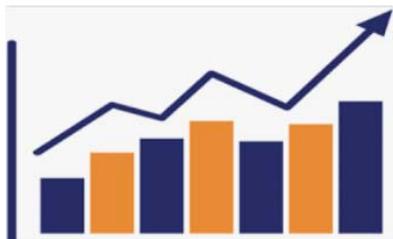
# About Me

## Ou Zhang



- **Ph.D./MA, Psychometrics** **2005-2012**
- **BS, Computer Science** **1997-2001**
  
- **Research Scientist/Team Lead, Pearson** **2012-present**
  - **Clinical Assessment (5 years)**
  - **School Assessment (3 years)**
  
- **3 Important things I devote to:**

### Statistics



### Programming



### Sports



# Topics

- **Background Information**
  - **Current ADHD diagnosis**
  - **Why the new ADHD diagnosis system is needed?**
- **Quotient Introduction**
  - **System development process**
  - **Psychometrics properties**
  - **Reporting system**
- **Summary & Takeaways**
- **Q & A**

# My role in this Project

- **Lead the Psychometrics parts of project**
  - **Theoretical research support**
  - **Analysis and raw score calculation**
  - **Norming/raw-to-scale transformation**
  - **Composite score**
  - **Validity**
- **Program the scoring algorithm codes for auto-reporting system (SAS)**
- **Coordinate and Tech Support**
  - **Software design & development**
  - **UX/ UI design and evaluation**
  - **Data collection and sampling plan**

# ADHD

- **Attention-deficit/hyperactivity disorder (ADHD) is the most common childhood neurobehavioral disorder.**
- **3 Core Symptoms of ADHD**
  - **Inattention**
  - **Hyperactivity**
  - **Impulsivity**

# Current ADHD Diagnosis

- **Comprehensive Clinical Evaluation**
  - **Portfolio of daily activities**
  - **Diagnostic and Statistical Manual of Mental Disorders, 5<sup>th</sup> Edition (DSM-5) criteria**
  - **ADHD rating scale or other survey instruments**

# Current ADHD Diagnosis (cont.)

- **DSM-5 criteria Example:**

People with ADHD show a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development:

1. **Inattention: Six or more symptoms of inattention for children up to age 16, or five or more for adolescents 17 and older and adults; symptoms of inattention have been present for at least 6 months, and they are inappropriate for developmental level:**
  - Often fails to give close attention to details or makes careless mistakes in schoolwork, at work, or with other activities.
  - Often has trouble holding attention on tasks or play activities.
  - Often does not seem to listen when spoken to directly.
  - Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (e.g., loses focus, side-tracked).
  - Often has trouble organizing tasks and activities.
  - Often avoids, dislikes, or is reluctant to do tasks that require mental effort over a long period of time (such as schoolwork or homework).
  - Often loses things necessary for tasks and activities (e.g. school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones).
  - Is often easily distracted
  - Is often forgetful in daily activities.

## Current ADHD Diagnosis (cont.)

- **Caveats of current ADHD Diagnosis Process**
  - Qualitative/Descriptive
  - Subjective
  - Affected by bias on the part of the parent/teacher informant
- **Caveats of actual ADHD Diagnosis Practice**
  - 2 of every 3 clinicians who receive little or no training in the clinical management of ADHD
  - Only **38%** of pediatricians use the DSM-5 criteria
  - Only **4%** follow guidelines for collecting ratings information
- **ADHD diagnosis → difficult**
- **Misdiagnosis/Error diagnosis**

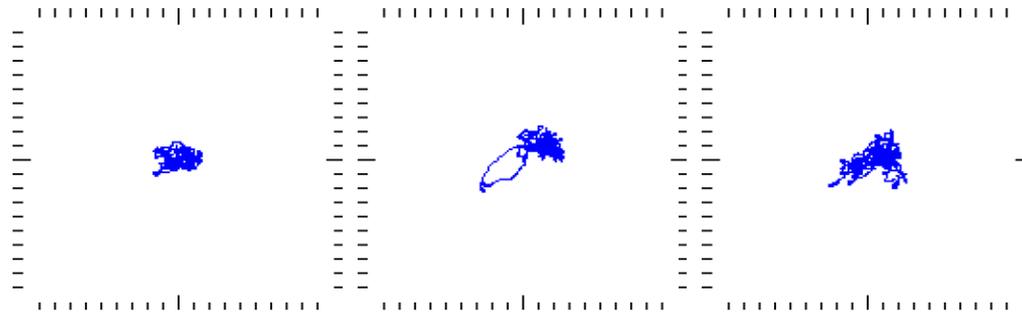
## **Current ADHD Diagnosis (cont.)**

- **We don't know → ADHD diagnosis results**
- **We know → Straightforward, easy-to-be-noticed ADHD symptoms**

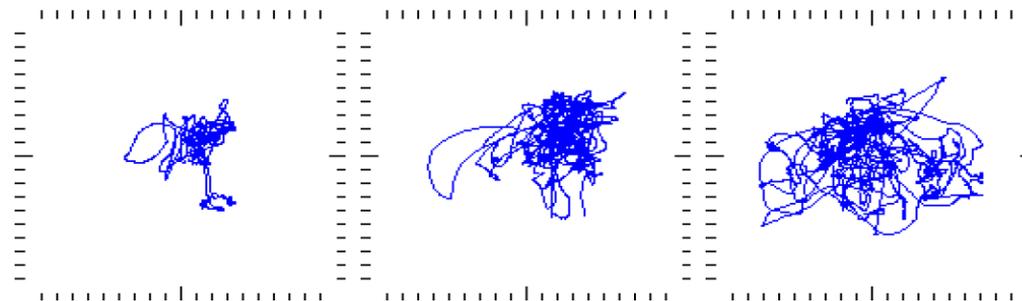
# ADHD Symptoms

- **Head Motion Track**

*9-year-old without ADHD*

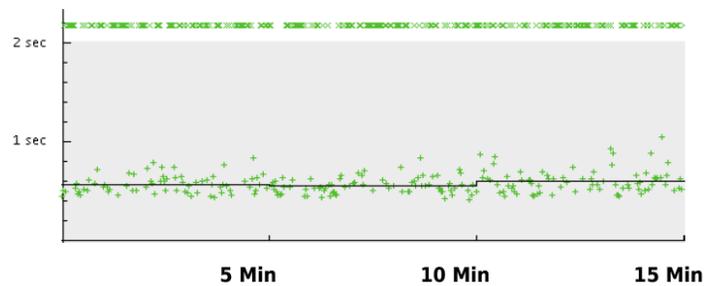
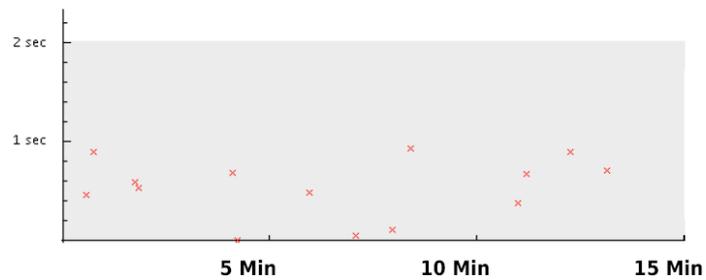


*9-year-old with ADHD*

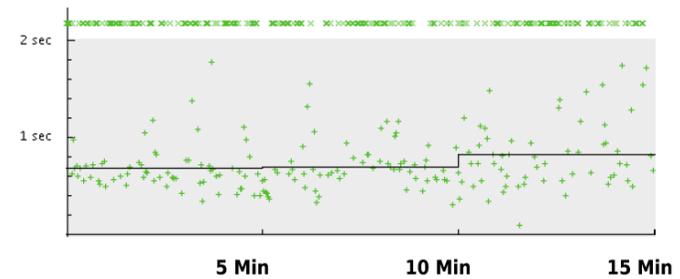
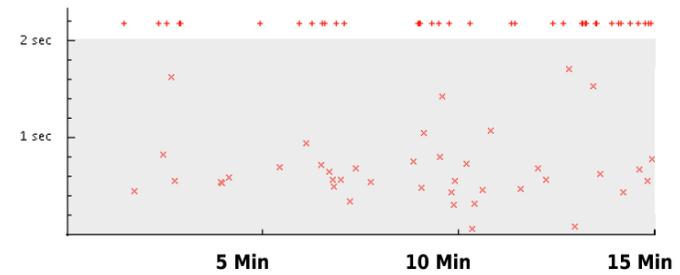


# ADHD Symptoms (cont.)

- **Attention Response Pattern**
  - Y-axis → responding time
  - **Red dots** → Error responses



***9-year-old without ADHD***



***9-year-old with ADHD***

**ADHD Symptom (cont.)**

# **ADHD Symptoms**



**Tool**



**Quotient ADHD System**

# Software Design & Development

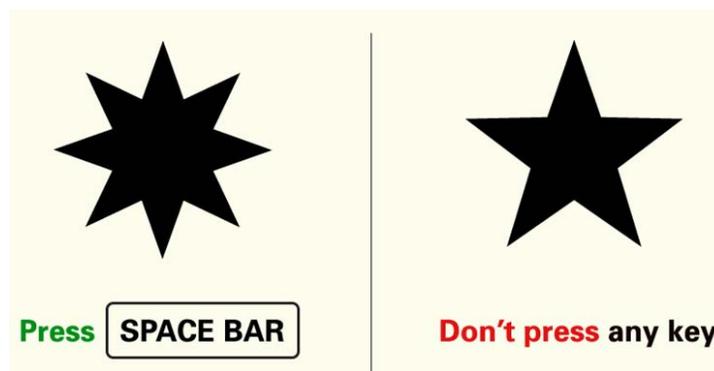
- **Computer-based system**



- **Initiated/developed (Harvard Medical School)**
- **Pearson (2014)**
- **Redesign/develop iPad version**
- **Fix/update algorithm**

## Software Design & Development (cont.)

- **15-minute test → attention fluctuation**
- **1 of 2 Stimuli every 2 seconds (episode)**

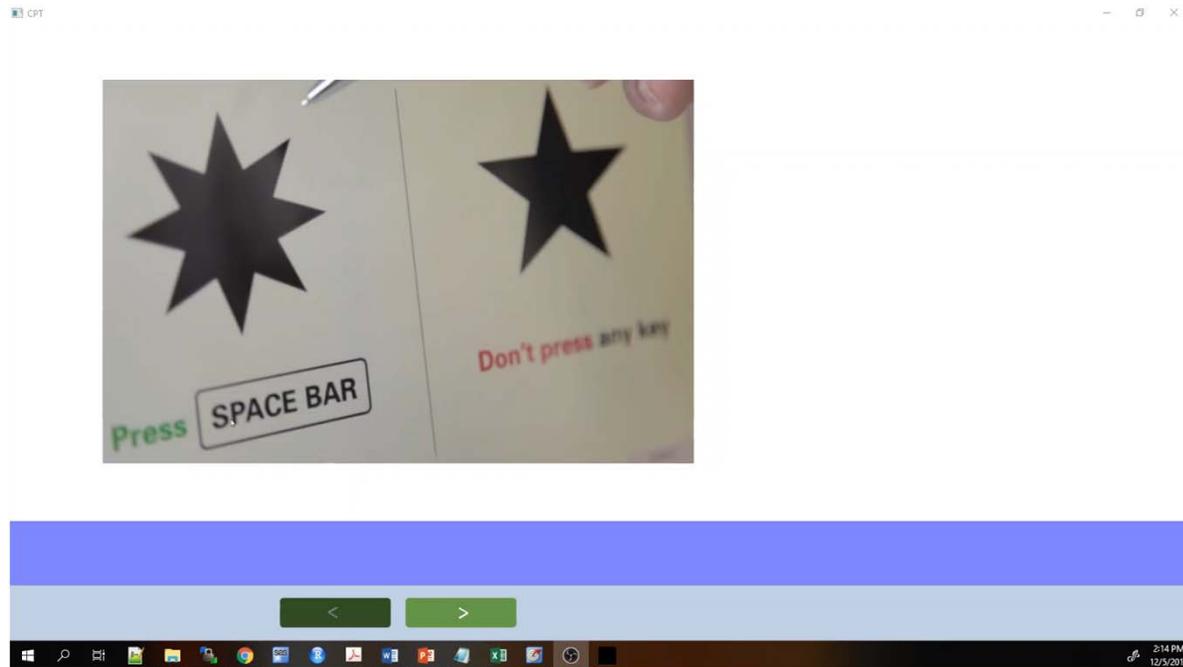


- **200 ms (stimuli) + 1800 ms (response time) = 2 seconds**
- **2 correct responses**
- **2 incorrect responses**

# **Software Design & Development (cont.)**

## **Demo**

# Software Design & Development (cont.)



# Software Design & Development (cont.)

- **Game-based platform on iPad**

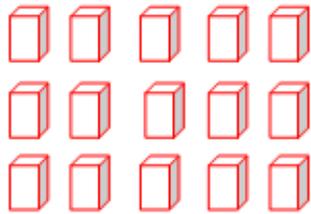
-  -- Target (Touch to Hammer it)

-  -- Non-target (Don't touch it)

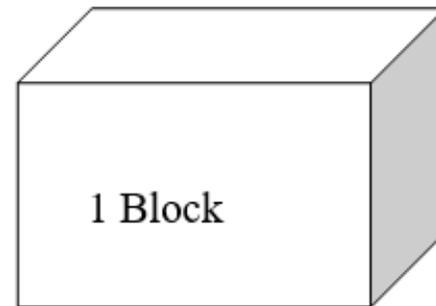
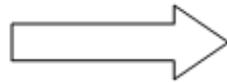


# Software Design & Development (cont.)

- **30-second state block (15 episodes)**

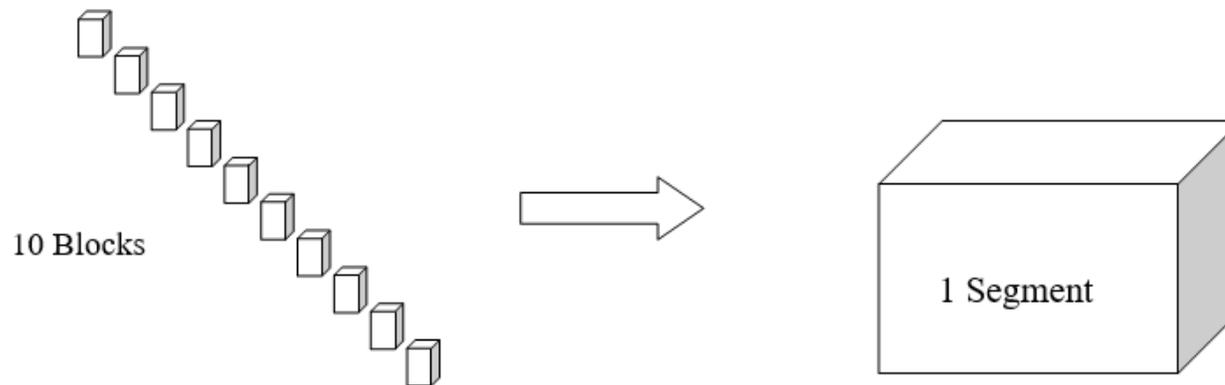


15 Episodes



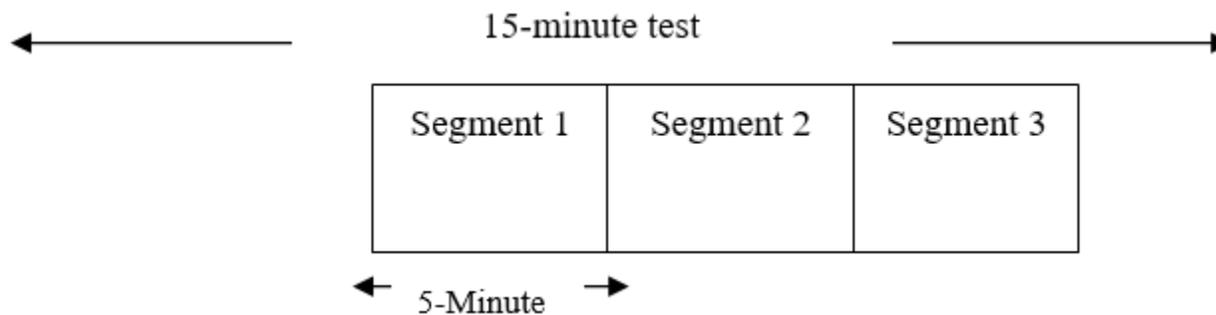
# Software Design & Development (cont.)

- **5-minute segment (10 blocks)**



## Software Design & Development (cont.)

- **15-minute test (3 segments)**



**15** episodes (block) x **10** blocks (segment) x **3** segments

**450** episodes

## **Software Design & Development (cont.)**

- **Raw responses to be collected from 450 episodes**
  - 1. Eye/Body movement range/area**
  - 2. Correct/incorrect response**
  - 3. Response time**

# Software Design & Development (cont.)

- **Software Testdeck Evaluation**
  - **Robot test**



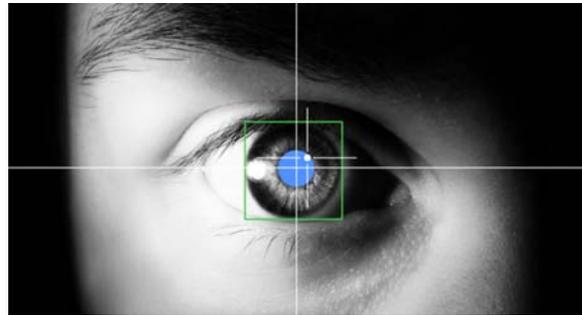
- **Raw data format conversion (JSON → .CSV → SAS format)**

# **Analysis & Raw Score Calculation**

- **3 Types of Analyses and Raw Score Calculation**
  - **Motion analysis**
  - **Attention response analysis**
  - **Attention state analysis**

## Analysis & Raw Score Calculation (cont.)

- **Motion analysis**
  - **Eye gazing tracking**



- **Body movement tracking**



## **Analysis & Raw Score Calculation (cont.)**

- **Motion analysis (Raw score calculation)**
  - **Movement: the number of position changes  $> 1\text{mm}$**
  - **Area: The total area covered by the eye/body motion**
  - **Displacement: The total distance moved of the eye/body motion**

## Analysis & Raw Score Calculation (cont.)

- **Attention response analysis**
  - **Accuracy:** % of correct responses
  - **Omission Errors:** % of missed targets
  - **Commission Errors:** % of incorrect responses to non-targets
  - **Latency:** Average time to respond correctly

# Analysis & Raw Score Calculation (cont.)

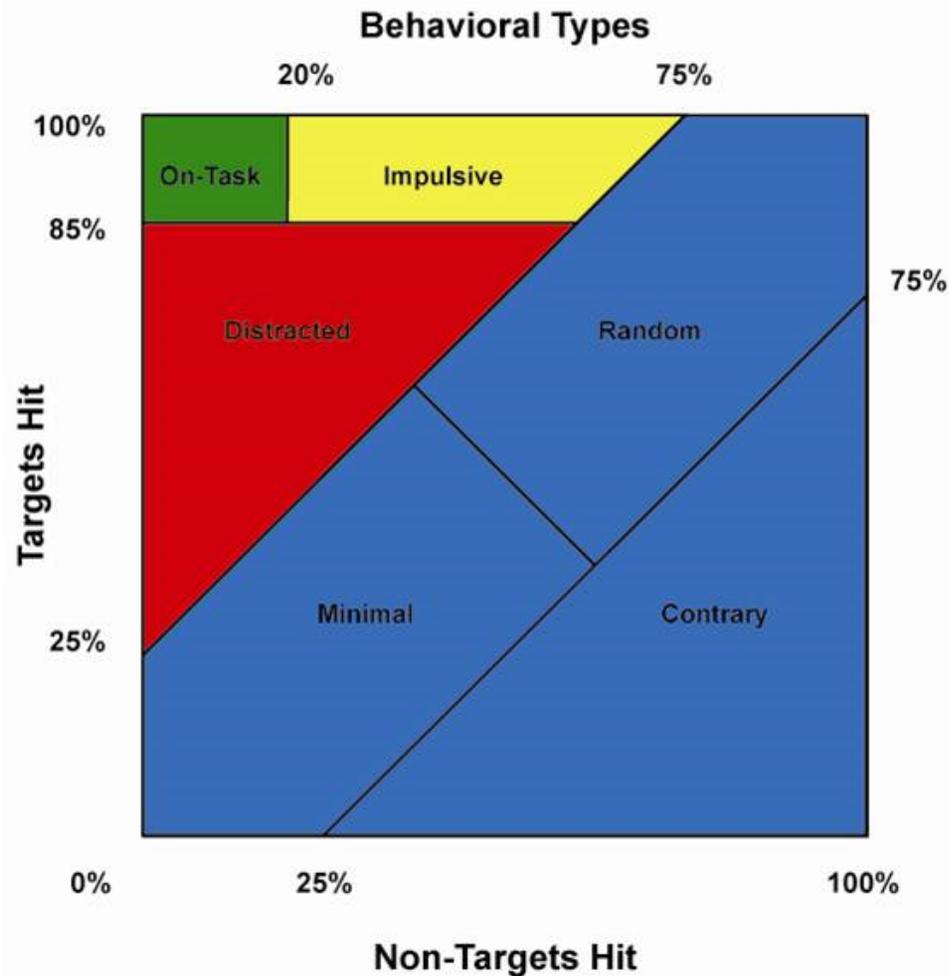
- **Attention state analysis**
  - **response patterns in a 30-second block and classifies the attention pattern as one of four attention states.**



- **Attentive:** Good level of accuracy (>85%) with limited errors
- **Impulsive:** Good level of accuracy (>85%) with significant errors of commission
- **Distracted:** Fair level of accuracy with significant errors of omission
- **Disengaged:** Accuracy no better than chance with a disengaged manner
  - **Random:** no better than random chance
  - **Minimal:** few responses, less than random chance
  - **Contrary:** significantly worse than random chance

# Analysis & Raw Score Calculation (cont.)

- **Attention state calculation chart**





# Data Collection & Sampling Plan

- **Sampling plan**
  - Stratified sampling based on 2014 US census results
  - Age: 6-12
  - Normative (male/ female)
  - Clinical (ADHD)
  - Retest
  - Cross-validation
    - ADHD-Rating Scale
    - Behavior Assessment System for Children, Third Edition (BASC-3)

Gender	Normative	Clinical	Retest	ADHD-RS	BASC-3
Male	636	74	42	110	112
Female	743	70	37	88	88

- **Sample stratification**

# Theoretical Research Support

- **30+ Quotient-related papers are published in the past 10 years.**

Teicher et al. *BMC Psychiatry* 2012, **12**:190  
<http://www.biomedcentral.com/1471-244X/12/190>



Does Placebo Response Differ Between Objective and Subjective Measures in Children with Attention-Deficit/Hyperactivity Disorder?

## RESEARCH ARTICLE

## Open Access

Hyperactivity persists in  
with ADHD and remains  
feature of the disorder: a

Martin H Teicher<sup>1,2\*</sup>, Ann Polcari<sup>1,2,3</sup>  
13:100

JOURNAL OF CHILD AND ADOLESCENT PSYCHOPHARMACOLOGY  
Volume 14, Number 2, 2004  
© Mary Ann Liebert, Inc.  
Pp. 219–232

Novel Strategy for the Analysis of CPT Data  
Provides New Insight into the Effects of  
Methylphenidate on Attentional States  
in Children with ADHD

Martin H. Teicher, M.D., Ph.D.,<sup>1,2</sup> Steven B. Lowen, Ph.D.,<sup>1,3</sup>  
Ann Polcari, Ph.D., R.N., C.S.,<sup>2</sup> Mary Foley, R.N., C.S.,<sup>2</sup> and Cynthia E. McGreenery<sup>2</sup>

Objec

P. He  
J. Fre  
J. Sm  
C. So  
P. M.  
J. Hebebrand  
H. Remschmidt

MARTIN H. TEICHER, M.D., PH.D., YUTAKA ITO, M.D., PH.D., CAROL A. GLOD, PH.D., R.N.,  
AND NATACHA I. BARBER, M.D.

after treatment with methylphenidate

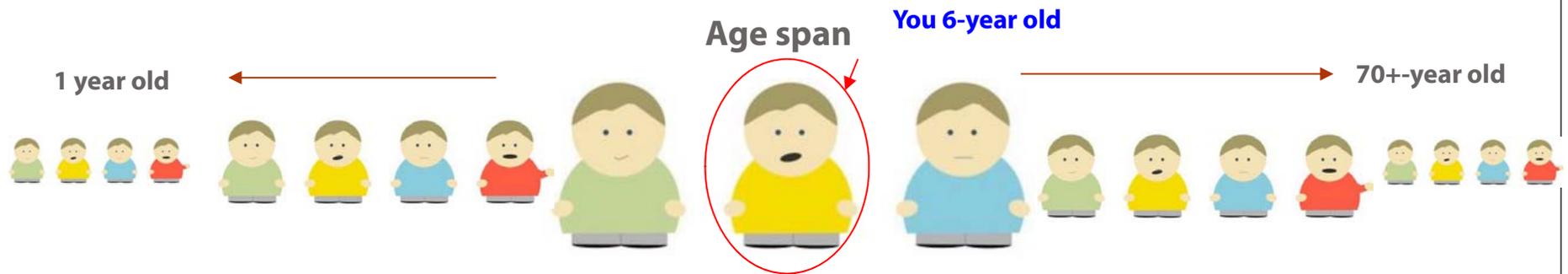
so response complicates the interpretation of treatment response in both clinical trials in youth with attention-deficit/hyperactivity disorder (ADHD). Comparing subjective ADHD symptom rating scales with scores obtained using ADHD System (an objective computerized technology for assessment of hyperactivity and impulsivity in ADHD), it was found that agreement between these 2 measures was as strong as anticipated. This observation prompted us to evaluate placebo response with subjective and objective assessments. Eligible study participants aged 7–17 years were randomized to 1 of 2 treatment sequences based on clinician interviews were randomized to 1 of 2 treatment sequences: low dose, and medium dose; or low dose, medium dose, and placebo) using methylphenidate HCl or osmotic controlled-release (OROS) methylphenidate HCl as the active agent in a double-blind (subject, parent, rater) trial. Subjects were exposed to 3 different doses to evaluate the comparative sensitivity of objective and subjective measures.

y,  
1

# Selected Bibliography of Quotient Publications

- Ohashi K, Polcari A, McGreenery C, Valente E, Teicher M. ADHD is Characterized by Multi-second Spikes in Motor Activity and Impaired Attention, New Research Poster, *Society of Biological Psychiatry*, 2007.
- Ohashi K, Teicher M. Unraveling the Nature of Hyperactivity in Children with Attention-Deficit Hyperactivity Disorder, *Archives General Psychiatry* 67(4): 388-396, 2010.
- Sumner CR, Sutton VK, Teicher M, Newcorn JH. Does Placebo Response Differ Between Objective and Subjective ADHD Measures? *Postgraduate Medicine* 122(5): 51-62, 2010.
- Sumner, CR (2010) New Tool for Objective Assessments of ADHD: The Quotient® ADHD System, *The ADHD Report*, editor Russell A. Barkley, 18(5): 6-10, 2010.
- Slaughter D, DiMartino A, Castellanos FX, et al. (2010) A Preliminary Examination of Resting State Functional Connectivity Correlates of Motor Activity. New Research Poster, Annual Meeting of the *American Academy of Child and Adolescent Psychiatry*, October, 2010.
- Teicher M.H., Polcari A, Fourligas N, Vitaliano G, and Navalta CP. (2012) Hyperactivity persists in male and female adults with ADHD and remains highly discriminative feature of the disorder: a case control study. *BMC Psychiatry* 12:190 (Article URL: <http://www.biomedcentral.com/1471-244X/12/190>)

# Raw-to-Scale Transformation Method



Content is not available!

# Composite Score

- **The composite scores provide an integrated view of the neural control functioning observed and a quantification of any deficits noted.**
  - **ADHD diagnostic composite score (System Index)**
  - **Motion composite score**
  - **Attention composite score**
  - **Global composite score** (Average of Attention and motion composites)
- **Weighting and final composite algorithm**
  - **Principal component analysis verification**
  - **Different weighting approaches**

# Validity

- **Test-retest reliability**
- **Sensitivity/Specificity**
- **Cross-product validation**

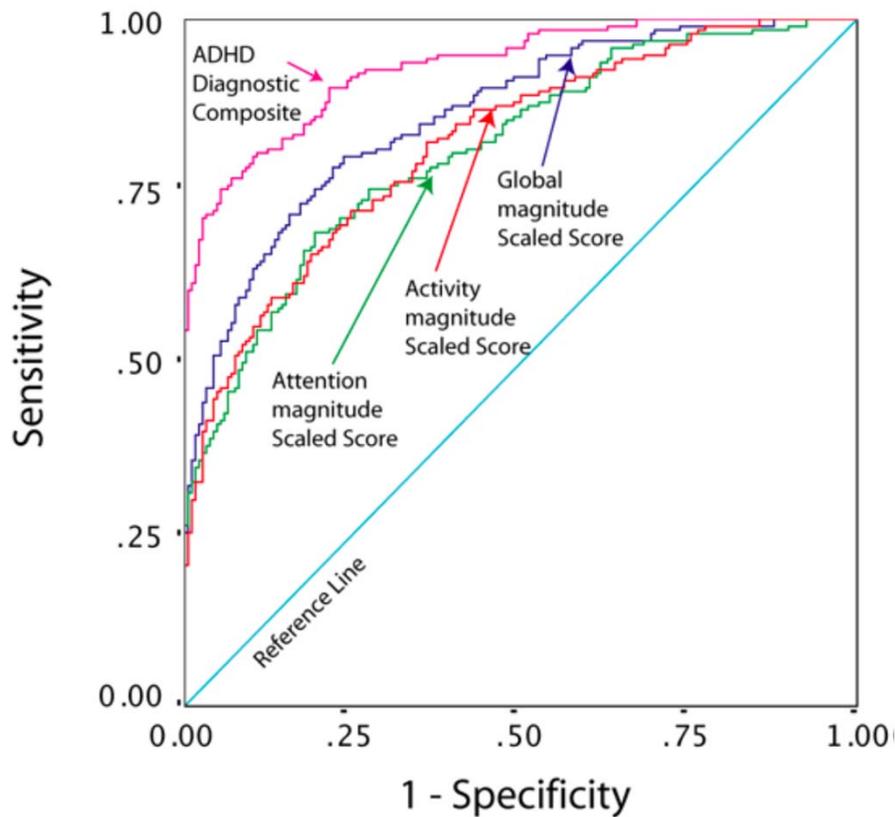
## Validity (cont.)

- **Test-retest reliability**
  - **Time interval: 60 minutes, 5 days**

Test/retest	Motion	Attention	System Index
60-minute	0.91	0.95	0.94
5 days	0.84	0.94	0.82

# Validity (cont.)

- **Sensitivity/Specificity**



## Area Under the Curve (AUC)

**Diagnostic Comp = 0.931**

**(System Index)**

**Global Scaled SS = 0.859**

**Act. (Motion) SS = 0.817**

**Attention SS = 0.810**

## Validity (cont.)

- **Cross-product ADHD diagnosis agreement**

<b>BASC-3</b>	<b>ADHD-RS</b>
0.88	0.84

## Quotient Report

- **Automated Report system → Patient ADHD diagnosis report**
- **Psychometrics → Program the scoring algorithm codes in SAS**
- **Software development → Report delivery system**
- **HTML/PDF format**

# Quotient Report

- **Mock Example:**

Patient Name:	Mr Ou
Age:	<b>13.08</b>
Grade:	<b>N/A</b>
Administration Date:	<b>Feb 24 2016 9:46 am</b>
Gender:	<b>Male</b>
Type of Report:	<b>Blue</b>
Report ID:	<b>225005</b>
Clinician:	<b>Stuart Red</b>

# Quotient Report (cont.)

Clinician Name: Stuart Red

Test Date: Feb 24 2016 9:46 am

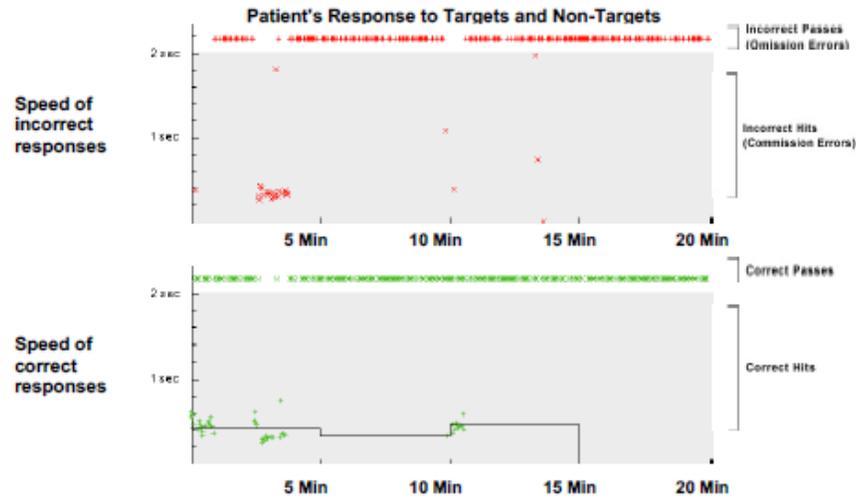
Patient Name: Mr Ou

Date of Birth: Jan 24 2003

Gender: M Age: 13.08 Grade: N/A

Comments:

## ATTENTION ANALYSES



Patient's Response Results

Measure	Results	Reference Range (16-84 Percentile)	Age Percentile ( $t \leq 16$ Age Percentile)
<b>Accuracy: (percent)</b> The percentage of correct responses.	53.3	76.2 - 95.8	N/A
<b>Omission Errors: (percent)</b> The percentage of missed targets (a measure of inattention).	86.1	6.4 - 10.5	N/A
<b>Commission Errors: (percent)</b> The percentage of incorrect responses to non-targets (a measure of impulsivity).	8.6	7.7 - 37.8	N/A
<b>Latency: (milliseconds)</b> The average amount of time to respond correctly (speed).	306	364-523	N/A
<b>Variability: (milliseconds)</b> The variation in response time to the correct target.	45	86 - 168	N/A
<b>C.O.V. (number)</b> A normalized measure of response time variation.	5	19 - 37	N/A

Report ID: 225005

# Quotient Report (cont.)

Clinician Name: Stuart Red  
 Patient Name: Mr Ou

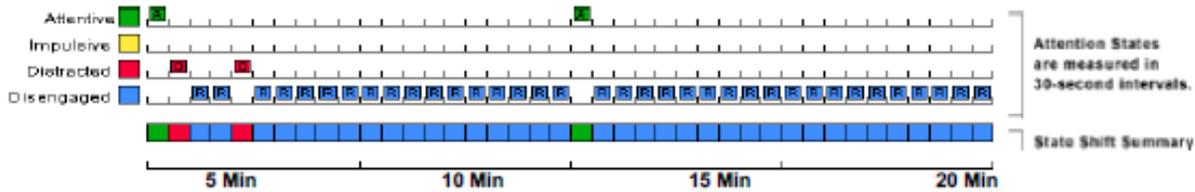
Test Date: Feb 24 2016 9:46 am  
 Date of Birth: Jan 24 2003

Gender: M Age: 13.08 Grade: N/A

Comments:

## ATTENTION ANALYSES CONTINUED

### Patient's Attention States During Testing



### Attention State Results

Measure	Results	Reference Range (16-84 Percentile)	Age Percentile (t ≤ 16 Age Percentile)
<b>Number of Shifts: (number)</b> <i>A measure of how many times a change in behavioral states occurs over the course of a test.</i>	6	6 - 20	N/A
<b>Attentive: (percent)</b> <i>Percent of 30 second blocks in which subjects performed with very high level of accuracy.</i>	5.0	16.7 - 90.0	N/A
<b>Impulsive: (percent)</b> <i>Percent of blocks when subjects performed better than chance but made a significant number of commission errors.</i>	0.0	6.7 - 52.5	N/A
<b>Distracted: (percent)</b> <i>Percent of blocks when subjects performed better than chance but missed a significant number of targets.</i>	5.0	0.0 - 13.3	N/A
<b>R. Random: (percent)</b> <i>Percent of blocks when subjects performed no better than predicted by random chance.</i>	7.5	0.0 - 13.3	N/A
<b>M. Minimal: (percent)</b> <i>Percent of blocks when subjects performed no better than predicted by random chance and made few responses.</i>	82.5	0.0 - 2.5	N/A
<b>C. Contrary: (percent)</b> <i>Percent of blocks when subjects performed worse than predicted by random chance.</i>	0.0	0.0 - 0.0	N/A

# Quotient Report (cont.)

Clinician Name: Stuart Red

Patient Name: Mr Ou

Test Date: Feb 24 2016 9:46 am

Date of Birth: Jan 24 2003

Gender: M

Age: 13.08

Grade: N/A

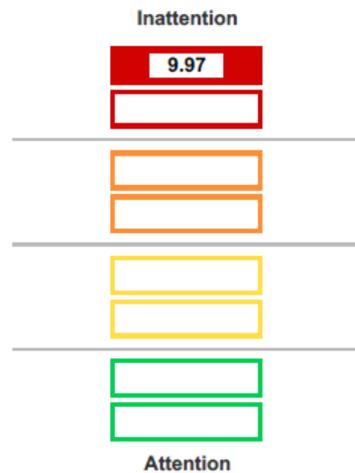
Comments:

## PEARSON SCALED SCORES

The Pearson System Scaled Score consists of:

- Attention Scaled Score - a composite of how this patient's attention compares to the community sample.

High scaled scores are associated with the scores that patients receive.



# Summary

- **Software development process**
- **UX/UI Research & Evaluation**
- **Sampling and data extraction**
- **Analysis and raw score calculation**
- **Norming/raw-to-scale transformation**
- **Composite score**
- **Validity**
- **Online Reporting system**

# Takeaways

- **The game-based assessment is so different from the traditional standardized assessment**
- **The process of quantifying an extremely-hard-to-be-measured latent construct is not an easy task**
- **Psychometrics is so essential. It ensures what we assess is what we expected to measure**
- **Early psychometrics involvement could be beneficial and add efficiency**
- **Communication and collaboration are the keys to success**

