# Visual Cognition and Dynamic Balance in Persons with Autism Spectrum Disorder

Ka-Lam Sam, Andrew W. Smith, and Lo Sing Kai

***Abstract*—Visual cognition and dynamic balance are distinguished as two crucial aspects for individuals with autism. Still, the relationship and/or contribution to the overall development between them are unclear. This study examines the relationship between these two domains for individuals with autism. Five males with autism (age: 20.8 ± 3.71) were involved in this study, and eight males without autism (age: 28.9 ± 4.52) were included as in comparison group. Measures included were Raven test for visual cognition and Pro Balance (Lab rehab™) test for dynamic balance. The results showed that non-autistic group (*M* = 117.75, SD = 44.89) [autistic group: *M* = 61.25, *SD* = 32.88] performed better in dynamic balance test (*p* <.05, *d* = -1.36); visual cognition was not a good predictor of dynamic balance and vice versa (*p* >.05); and, dynamic balance and body weight seems negatively correlated (*r* = -.993, *p* < .05). Although lower dynamic balance in autistic group was found in this study, a more comprehensive comparison was recommended still for further investigations.**

***Index Terms*—Autism, visual cognition, dynamic balance.**

## I. Introduction

Autism Spectrum Disorder (ASD) was described in Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5), mainly in three aspects of daily life below: 1) tenacious deficits in social functioning; 2) restrictive, repetitive pattern of behavior, interests or activities; and 3) with or without accompanying intellectual/language/motor impairment [1]. Studies have found balance difficulties and postural abnormalities exist in autism [2], [3] and some have proposed that visual cognition might be one of the key possible factors which impact dynamic balance and postural control [3], [4].

Visual cognition is the ability to perceive an object's physical properties (such as shape, color and texture) and apply semantic attributes to the object (visual object-recognition), interpret the surrounding environment by processing information that is contained in visible light/ eyesight (visual perception), and involves the visual cortex (dorsal stream; ventral stream).

Dynamic Balance is the ability to maintain equilibrium with minimal postural sway in a dynamic scenario requiring coordination of input from multiple sensory systems including: vestibular, somatosensory, and visual systems (sensorimotor control); subtype of balance (static/dynamic balance).

Mache and Todd (2016) conducted a study investigating the relationship between gross motor skills of lower limb and postural stability in children with ASD. The authors found that postural stability might influence the ability of children to perform gross motor skills. However, their study did not consider the visual input alone, and will the postural stability be affected by it. The authors pointed out that visual input and cognition might be two crucial factors that influencing the postural stability [2].

Another two studies by Stins *et al.* (2015) and Hanaie *et al.* (2016), focusing on stability and dynamical complexities/ sensory contributions, also indicated that the dynamic balance might associate with visual cognition among individuals with ASD [3], [5].

In addition, studies have noted postural abnormalities, in both dynamic and static balance, in the population of ASD [4], [6]-[8]. The summary of the latest studies (in the recent two years) were shown in Table I.

TABLE I: (Summary of The Latest Seven Studies on Visual Cognition and Dynamic Balance or Related Fields in Persons with Autism

| Study | Subject | Design/ Intervention |
|---|---|---|
| Brunsdon et al. (2015) | 341 (181 ASD; 160 Non-ASD) | Comparison |
| Burrows et al. (2016) | Across 3 age cohorts (large samples) | Comparison |
| Hanaie et al. (2016) | 39 (19 ASD; 20 Non-ASD) | Comparison |
| Hellendoorn et al. (2015) | 453 (63 ASD; 269 T1; 121 T2) | Comparison |
| Lee et al. (2016) | 116 (63 reassessed after 6 months) | Scale validation; review the cognitive and motor domain |
| Mache et al. (2016) | 22 (11 ASD; 11 Non-ASD) | Comparison |
| Stins et al. (2015) | 18 (9 ASD; 9 Non-ASD) | Comparison |

TABLE II: (Continuous)

| Study | Measure | Outcome |
|---|---|---|
| Brunsdon et al. (2015) | Cognitive battery | Multiple cognitive atypicalities appear in ASD group |
| Burrows et al. (2016) | Resting-state functional connectivity (rsFC); posterior cingulate cortex (PCC) | Neurotypical adults exhibited stronger rsFC of the PCC with orbitofrontal cortex compared with adults with ASD |
| Hanaie et al. (2016) | Movement Assessment Battery for Children 2 (M-ABC 2) | Children with ASD showed poorer motor performance than did the controls |

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| | | |
|---|---|---|
| Hellendoorn et al. (2015) | Visuospatial cognition; motor functioning | In line with the embodied cognition theory; motor and cognition was related |
| Lee et al. (2016) | Psychoeducational Profile-Third Edition (PEP-3) | The short form of PEP-3 showed a similar characteristics to the original one; state out the possible relationship between cognition and motor development |
| Mache et al. (2016) | Test of Gross Motor Development-3 (TGMD-3); Repetitive Behavior Scale-Revised (RBS-R); Force plate for postural sway, Center of Pressure (CoP) | Postural stability appears to influence the ability of children to perform gross motor skills |
| Stins et al. (2015) | Movement Assessment battery for children; M-ABC2; CoP | No group differences were found; suggest to test vision and motor adjustments in ASD |

Visual cognition and dynamic balance are identified as two key domains for persons with ASD in the recent publications (Table I). However, little is known about their relationship and/or contribution to the overall developmental aspect. The purpose of this study is to examine these two domains in persons with autism and try to reveal the relationship in-between.

## II. Method

### A. Participants

Five males with ASD (age: 20.8 ± 3.71) were recruited from Special Olympics Singapore with informed consent; and eight males without ASD (age: 28.9 ± 4.52) were recruited later in the National Institute of Education Singapore as in comparison group (Table II). Raven's Progressive Matrices and Pro Balance by Lab rehab™ were used to assess visual cognition and dynamic balance, respectively.

TABLE III: (TABLE II: Height and Weight by Group

| Group | N | Height | Weight | BMI |
|---|---|---|---|---|
| ASD | 5 | 173 ± 4 | 74 ± 7 | 25 ± 7 |
| Non-ASD | 8 | 176 ± 3 | 71 ± 5 | 23 ± 6 |

*Note: height in cm; weight in kg; BMI refers to Body Mass Index*

### B. Measures

Raven's Progressive Matrices (RPM) was developed in United Kingdom by John C. Raven in 1937. It is a visual cognition test which takes a maximum forty minutes to complete. There are five subsets in the test: 12 items in each subset. It is an indicator of cognitive development (Fig. 1).

Pro Balance was developed in Singapore by Lab rehab™ in 2007. It was adopted as an indicator for some exercise rehabilitation programs in health-related sectors, i.e., clinics, hospitals, labs, etc. During the test, participant was asked to stand quietly on an electronic balance disc with both feet and with eyes open for 30 s. The device records the, center of gravity (CoG) as it moves during the trials. For each subject, there were 3 trials in total, 30 seconds per trial, and 3 minutes' rest for each trial (Fig. 2).

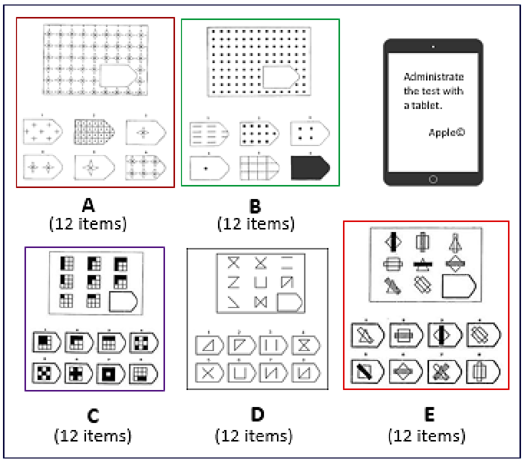


Fig. 1. Test of visual cognition.

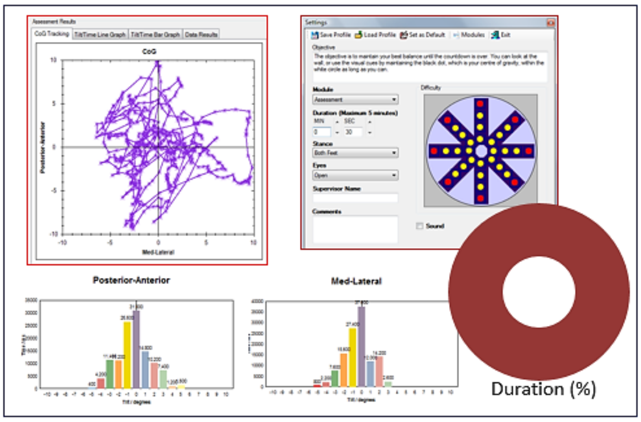


Fig. 2. Test of dynamic balance.

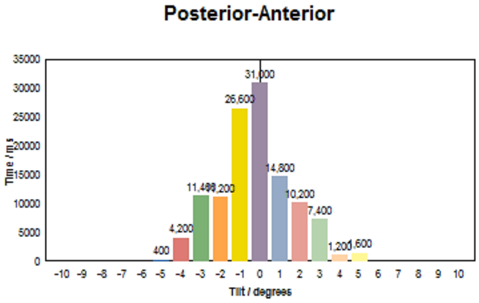


Fig. 3. Posterior-Anterior shifting diagram.

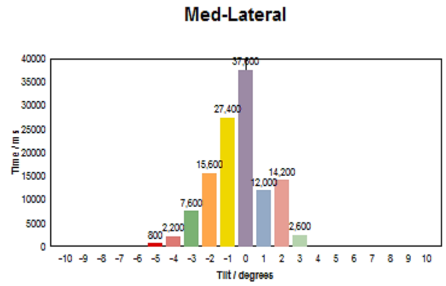


Fig 4. Medio-Lateral shifting diagram

Three components were used in calculating the dynamic balance score: 1) duration ratio (the percentage duration while standing inside the white area in the center; 2) Anterior/posterior degree ratio (A/P ° ratio) indicating the forward and backward swaying of the body (Figure 3); and 3)

Medio/lateral degree ratio (M/L °ratio) indicating the left and right swaying of the body (Fig. 4).

The swaying of body, center of gravity (CoG), was tracked; CoG tracking samples (by order: low, medium, and high postural control scores reflected by CoG shifting) were shown below (Fig. 5).

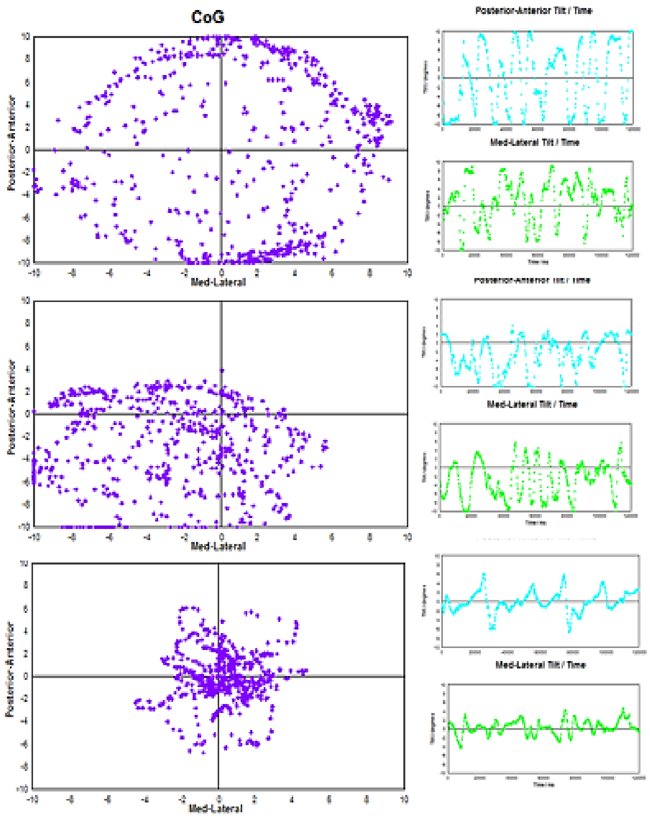


Fig. 5. Tracking of center of gravity (CoG).

### C. Data Analysis

Independent samples t-test, Pearson correlation, and regression analysis were adopted for the analytical procedure.

## III. Results

The results showed that non-ASD group ($M$ = 117.75, SD = 44.89) performed better than the ASD group ($M$=61.25, SD = 32.88) in dynamic balance test ($p < .05$, $d$ = -1.36), Figure 6; visual cognition was not a good predictor of dynamic balance and vice versa ($p > .05$), Table III; and, dynamic balance and body weight seems negatively correlated ($r$ = -.993, $p < .05$), Table IV.

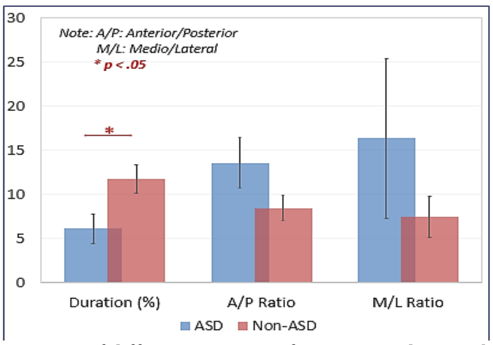


Fig. 6. Comparison of different parameters for assessing dynamic balance

TABLE IV: (Regression Coefficient of Visual Cognition Predicting Dynamic Balance

| Variable | Unstandardized Coefficients B | Unstandardized Coefficients Standard Error | Standardized Coefficients Beta | t-value | $p$ |
|---|---|---|---|---|---|
| (Constant) | 16.492 | 7.720 | | 2.136 | .166 |
| Dynamic Balance | .127 | .114 | .617 | 1.108 | .383 |

TABLE V: (Correlation Coefficients

| | Height | Weight | BMI | Raven |
|---|---|---|---|---|
| Dynamic Balance | .152 | -.993** | -.904 | .617 |

** $p < .01$

## IV. Discussion

Visual cognition and dynamic balance for persons with ASD were two important aspects; the results were redrawn the attention of balance control in people with autism. Similar to the current literatures [2]-[5], the relationship between visual cognition and dynamic balance were investigated incoherently (inconsistent in those findings). Potential factors affecting the results were discussed below.

### A. Neuromuscular Conditions of the Postural Control

In the aspect of neuromuscular conditions, the functioning of somatosensory receptors is a crucial factor which affect the balance/postural control while encountering a changing (dynamic) scenario. After a certain training on extremity and/or trunk strategies, it will programmed inside automatically for those receptors, once the sensors receive any signal from external stimulation, the system of maintaining body equilibrium/balance was activated immediately. If further studies are conducting based on the neuromuscular factor, i.e., for those somatosensory receptors, the use of electromyography (EMG) measure is recommended, since it provides proprioceptive signals (the primary source of autonomic proprioceptive input). Although extremity proprioceptive systems are not entirely understood, they remain an important link in dynamic postural control.

### B. Somatotyping Conditions of the Postural Control

The body anthropometric measurements, such as the body type and/or body shape, are internal factors which may partially affect the balance/postural control in human body. In layman term, higher center of gravity (CoG) seems to be more difficult to maintain the body balance in a standing position.

### C. Obesity and Postural Control

The BMI range of the autistic participants varied from underweight to obese (BMI: 25 ±7 in Table II), and the mean falls in the overweight category of the Asian population. Physiologists have been investigating the issue of obese and postural/balance control for a few decades; but most of them were applicable for general population only; the conclusion is lower CoG due to obese do not contribute to a better balance control, and might even make the situation worse. Besides, the hot issue these years was the obese and cognition, it was believed that the cognitive deficits lead to obese, but the relationship in-between still needs evidences to prove/support; further work/ discussion should carry out.

### D. Challenging for Individuals with Autism

Since the unique characteristics of people with autism, i.e., lack of socialization skills, deficit on language/ communication, restricted behaviors, etc., which make the exercise inclusion a harder task for accomplishment. A certain research work should do on that in order to justify their needs with evidence; and sufficient support should be provided.

### E. Emphasizing the Needs of Physical Training/Activity

However, we still believe that training the muscle strength required for maintaining body balance is important ; hence, training plans in those fields are suggested. Second, persistently developing the functional cognition for executing daily basic tasks is crucial as well. Such health services, i.e., occupational therapy, physical therapy, etc., are expected on high demand for persons with autism.

### F. Limitations

Since only male subjects were included in this study, it would induce gender bias; the anatomical difference might lead to various CoGs, those variations might possibly affect the dynamic balance/posture control as a result; however, autism is a male dominated disorder, most of the individuals with autism are boys/men (instead of girls/women), roughly 4:1 in ration [1];on the other hand, the limited sample size in this study (laboratory context) might encounter with statistical threats, which might lead to over-interpret the results regardless of how representativeness of the samples are.

## V. Conclusion

The results recently could not confirm that the dynamic balance and visual cognition were two closely related aspects for people with ASD. Besides, it was indicated that lower scores on dynamic balance performance for ASD individuals comparing to their control counterparts. Since various constraints could not be avoided in this study, the interpretation of the initial findings should be sounded with cautious. A comprehensive comparison, considering neuromuscular, mechanical, somatotype, and etc., was recommended in the future explorations/studies.

## Appendix

*Score summary of the ASD participants* (informed consent obtained); did not assess the RPM of non-ASD participants due to the infeasibility/ inappropriate of administration

| Subject | BMI | RPM Score |
|---|---|---|
| AX001 | 18.82 | 33 |
| AX002 | 25.89 | 30 |
| AX003 | 34.52 | 20 |
| AX004 | 17.77 | 30 |
| AX005 | 26.41 | 17 |

*BMI: Body Mass Index; RPM: Raven's Progressive Matrices*

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