Cognitive Visual Dysfunctions in Children with Autism Spectrum Disorders and Other Developmental Delays

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Research article

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Abstract

Background: Autism spectrum disorders (ASD) are a group of neurodevelopmental disorders characterized by a triad of social, communicative, and imaginative impairments. Although early detection and intervention are important to improve functional outcomes in ASD, similar features between ASD and other developmental delays may impede timely diagnosis. In this study, we aimed to investigate the feasibility of Cognitive Visual Assessment Questionnaire (CVAQ) in differentiating ASD from other developmental delays.

Methods: We retrospectively reviewed the medical records of 115 pediatric patients (80 males, 35 females) with ASD and other developmental delays who had the Modified Checklist for Autism in Toddlers (M-CHAT) and CVAQ performed at Uijeongbu St. Mary's Hospital from January 2017 to June 2019.

Results: The mean age at M-CHAT and CVAQ was 31.8 months (range, 14.1 – 48). The proportion of ASD was significantly higher in patients with screen-positive M-CHAT than those with screen-negative M-CHAT (P = 0.035). The sensitivity of CVAQ for detecting ASD was 83.3% and 94.1% in 14.1 – <24 months and 24 – <36 months age groups, respectively. Among patients with screen-negative M-CHAT, the mean number of failed tasks related to dorsal stream pathway was greater in ASD compared to other developmental delays, although the differences were not statistically significant (P = 0.437).

Conclusions: Our study demonstrates that autistic individuals may have a specific impairment in dorsal stream functioning. CVAQ also showed improved sensitivity for detecting ASD in toddlers. When coupled with clinical observation and judgement, CVAQ is a useful alternative screening tool for differentiating ASD from other developmental delays in young children.

Background

Autism spectrum disorders (ASD) are a group of neurodevelopmental disorders characterized by persistent impairments in social interaction, verbal and non-verbal communication, repetitive and restricted behaviors, interests, and activities [1]. The prevalence of ASD has risen considerably in recent years [2] and there has been a significant shift in awareness of autism and demands for community services and interventions [3].

ASD is a lifelong condition that affects both the individual and the family, and accurate diagnosis of ASD during early development is important to receive timely and proper intervention [4, 5]. Previous studies emphasized that early intervention in ASD improves long-term developmental outcomes and yielded better outcomes for affected children and their families [6–8]. However, it is difficult to detect ASD in young children; children with ASD and other developmental delays, such as global developmental delay (GDD) and developmental language delay (DLD), may have similar features [9–11]. The average age of diagnosis with ASD has been reported to range from 3.6 years to almost 7 years of age [12].

Attention orienting is a cognitive process that enables moving attention focus from one location to another in response to a stimulus [13]. Deficits in attention orienting are consistently reported in ASD; individuals with ASD have early impairments in attention across multiple domains, including visual orienting and auditory paradigms [14–16]. It has been postulated that social deficit characteristics of ASD may be ascribed to attention orienting dysfunction [17]. Also, impaired attention orienting may precede social deficits and represent one of the earliest signs of ASD [18]. Although research investigating atypical attention networks in autism have been conducted [13], there are few data on implementation of cognitive visual assessment as a screening tool for autism in clinical practice.

In this study, we aimed to identify cognitive visual impairments specific to children with autism using the Cognitive Visual Assessment Questionnaire (CVAQ) and evaluate the feasibility of this instrument as a screening tool for differentiating ASD from other developmental delays.

Methods

Patients

A retrospective medical chart review was performed on pediatric patients who were screened using M-CHAT and CVAQ. Subjects were recruited from January 2017 to June 2019. The diagnosis of ASD and other developmental disorders, including GDD and DLD, were based on the Bayley Scales of Infant Development, 3rd edition and Diagnostic and Statistical Manual of Mental Disorders, 5th edition. Those who did not complete the evaluation or who were lost to follow-up were excluded from the study.

Screening instruments

The M-CHAT is a 23-item yes/no parent report screening instrument for ASD in children aged from 16 months to 4 years [19–21]. A positive M-CHAT was defined as failure of 3 or more total items or 2 or more of 6 critical items. Critical items included functions concerning joint attention (proto-declarative pointing, following a point, and bringing objects to show), social relatedness (interest in other children and imitation), and communication (responding to name) [22].

CVAQ consists of 23 items evaluating two stream model of visual processing, and parents were asked to rate items on a scale of 1 to 4 (1 being 'never', 2 being 'occasionally', 3 being 'most of the time', and 4 being 'always'). A ventral visual stream projecting to the temporal cortex is implicated in both object and face recognition, whereas a dorsal visual stream leading to the parietal cortex is associated with spatial location of objects and their relation to each other [23]. The items were as follows: how often children experienced difficulties recognizing people, shapes, and colors, whether children had problems finding their way around, and whether children had difficulties distinguishing objects from their background and from one another [24]. Table 1 lists the questions that were asked.

Table 1
Cognitive visual assessment questionnaire

1. Does your child recognize you before you speak?
2. Does your child recognize other family members?
3. Does he/she have difficulty reaching out for and grasping objects?
4. Can your child find objects hidden under a blanket?
5. Can your child pick up small objects with thumb and index finger?
6. Is your child able to see moving objects? (e.g. rolling ball)
7. Is your child able to see fast moving objects? (e.g. vehicles)
8. Does your child eat food from only one part of the plate and ignore the rest?
9. Can your child recognize objects?
10. Does your child recognize people from photographs?
11. Can your child identify himself/herself from photographs?
12. Does your child recognize friends?
13. Can your child recognize shapes?
14. Can your child name colors?
15. Can your child match colors?
16. Does your child have difficulty distinguishing a step from a line on the ground?
17. Does your child have difficulty seeing objects when he/she is moving quickly him/herself?
18. Can your child find objects on a patterned carpet?
19. Can your child find objects in complex pictures?
20. Does he/she lose objects around the house?
21. Can your child find his/her way around the house?
22. Does he/she misjudge going through doorways or along corridors?
23. Can your child find his/her way around new surroundings?

[Table 1 TO BE PLACED HERE]

Clinical analysis

Demographic and clinical data, including gender, age at screening, results of Bayley Scales of Infant Development, M-CHAT, and CVAQ, and final developmental diagnosis were collected.

Based on M-CHAT results, patients were allocated into groups of children who screened positive or negative on M-CHAT with a final diagnosis of ASD, GDD, or DLD. Differences in impaired dorsal and ventral visual stream functioning were assessed among patients with ASD, GDD and DLD.

All statistical analyses were performed with SPSS 21.0 for Windows (IBM Corp., Armonk, NY, USA), using the Fisher's exact test, Mann-Whitney test, and Kruskal-Wallis test to compare demographic and clinical characteristics by M-CHAT results and final diagnosis of developmental domains. Statistical significance was defined at $P < 0.05$.

Ethical approval for this retrospective study was provided by the Institutional Review Board (IRB UC20RASI0035).

Results

Patient characteristics

A total of 115 pediatric patients (80 males, 35 females) screened using M-CHAT and CVAQ were identified. The mean age at M-CHAT and CVAQ was 31.8 months (range, 14.1–48). Of 115 patients, 34 patients (29.6%) were finally diagnosed with ASD, 32 patients (27.8%) were diagnosed with GDD, and 49 patients (42.6%) were diagnosed with DLD.

Patients were grouped by M-CHAT results: Group A (children who screened positive on M-CHAT and were eventually diagnosed with ASD, GDD, or DLD; n = 85); and group B (children who screened negative on M-CHAT and were finally diagnosed with ASD, GDD, or DLD; n = 30). The mean age at M-CHAT and CVAQ was 30.4 months (range, 14.1–48) and 35.6 months (range, 23.6–46.4) for patients in group A and group B, respectively (P = 0.929).

Of 85 patients with screen-positive M-CHAT, 30 (35.3%) were diagnosed with ASD, 28 (32.9%) were diagnosed with GDD, and 27 (31.8%) were diagnosed with DLD. Of 30 patients with screen-negative M-CHAT, 22 (73.4%) were eventually diagnosed with DLD, 4 (13.3%) were diagnosed with ASD, and the remaining 4 (13.3%) were diagnosed with GDD. The proportion of ASD was significantly higher in patients with screen-positive M-CHAT than in those with screen-negative M-CHAT ($P < 0.05$). Conversely, the proportion of DLD was notably higher in patients with screen-negative M-CHAT than in those with screen-positive M-CHAT ($P < 0.05$) (Table 2).

Table 2
Patient characteristics

	Positive M-CHAT screening (n = 85)	Negative M-CHAT screening (n = 30)	*P* value
Gender (Male)	59 (69.4)[a]	21 (70)[a]	1.00
Age (months) at M-CHAT and CVAQ, mean (range)	30.4 (14.1–48)	35.6 (23.6–46.4)	0.929
Final diagnosis			
ASD	30 (35.3)[a]	4 (13.3)[a]	0.035
GDD	28 (32.9)[a]	4 (13.3)[a]	0.057
DLD	27 (31.8)[a]	22 (73.4)[a]	<0.001

M-CHAT, Modified Checklist for Autism in Toddlers; CVAQ, Cognitive Visual Assessment Questionnaire; ASD, autism spectrum disorder; GDD, global developmental delay; DLD; developmental language delay

[a]Values are percentages (%).

[Table 2 TO BE PLACED HERE]

Accuracy of cognitive visual assessment in detecting ASD

The sensitivity, specificity, positive predictive value, and negative predictive value of CVAQ in detecting children with ASD were 82.4%, 25.9%, 31.8%, and 22.2%, respectively. Table 3 shows the accuracy of CVAQ in distinguishing autistic children according to different age groups. The sensitivity of CVAQ in patients aged 14 – <24 months and 24 – <36 months were 83.3% and 94.1%, respectively. Conversely, the sensitivity in patients aged 36–48 months was 63.6%. The specificity of CVAQ in patients aged 14 – <24 months was 5.9%; it improved to 14.7% and 46.7% in patients aged 24 – <36 months and 36–48 months, respectively.

Table 3
Accuracy of cognitive visual assessment in detecting ASD by age groups

	Age (months) at CVAQ performed		
	14 – <24	24 – <36	36–48
Sensitivity (%)	83.3	94.1	63.6
Specificity (%)	5.9	14.7	46.7
PPV	23.8	35.6	30.4
NPV	50	83.3	77.8

ASD, autism spectrum disorder; CVAQ, Cognitive Visual Assessment Questionnaire; PPV, positive predictive value; NPV, negative predictive value

[Table 3 TO BE PLACED HERE]

Distribution of visual processing impairment within screen-positive M-CHAT group

The demographic and clinical characteristics of patients who screened positive on M-CHAT are shown in Table 4. Males comprised more than two thirds of patients with ASD and GDD, which was significantly greater than those with DLD ($P < 0.05$). The mean age at M-CHAT and CVAQ was 30.8 months (range, 18–47.7), 30.8 months (range, 14.1–43), and 29.6 months (range, 18.5–48) for patients with ASD, GDD, and DLD, respectively ($P = 0.697$).

Table 4
Comparison of demographic and clinical characteristics within positive M-CHAT screen group

	ASD (n = 30)	GDD (n = 28)	DLD (n = 27)	*P* value
Gender (Male)	23 (76.7)	22 (78.6)	13 (48.1)	0.014*
Age (months) at M-CHAT and CVAQ, mean (range)	30.8 (18–47.7)	30.8 (14.1–43)	29.6 (18.5–48)	0.697
Number of failed tasks related to the ventral visual stream, mean (range)	2.0 (0–6)	1.8 (0–6)	1.7 (0–3)	0.770
Number of failed tasks related to the dorsal visual stream, mean (range)	1.3 (0–7)	0.8 (0–7)	0.9 (0–7)	0.473

M-CHAT, Modified Checklist for Autism in Toddlers; ASD, autism spectrum disorder; GDD, global developmental delay; DLD; developmental language delay; CVAQ, Cognitive Visual Assessment Questionnaire

[a]Values are percentages (%).

[b]Proportion of males was significantly higher in ASD and GDD group than DLD group.

For tasks involving the ventral visual stream pathway, patients with ASD failed to perform a mean of 2.0 tasks (range, 0–6), while those with GDD or DLD failed to execute a mean of 1.8 tasks (range, 0–6) and 1.7 tasks (range, 0–3), respectively. No statistically significant difference was observed among the three groups in the number of failed tasks related to the ventral visual stream pathway ($P = 0.770$).

Regarding the dorsal visual stream pathway, patients with ASD failed to achieve a mean of 1.3 tasks (range, 0–7), while those with GDD or DLD failed to perform a mean of 0.8 tasks (range, 0–7) and 0.9 tasks (range, 0–7), respectively. The ASD group had a higher number of failed tasks related to the dorsal visual stream pathway than the GDD or DLD group, although the differences were not statistically significant ($P = 0.473$).

Patients were subdivided into two groups: ASD group (n = 30) and GDD or DLD group (n = 55). No significant difference in gender distribution or mean age at M-CHAT and CVAQ were observed between these two groups. The mean number of failed tasks related to the ventral visual stream pathway was 2.0 tasks and 1.7 tasks in the ASD group and GDD or DLD group, respectively, which was not significantly different ($P = 0.526$). In addition, the mean number of failed tasks related to the dorsal visual stream pathway was 1.3 tasks and 0.8 tasks in these two groups, respectively ($P = 0.223$).

[Table 4 TO BE PLACED HERE]

Distribution of visual processing impairment within screen-negative M-CHAT group

The demographic and clinical characteristics of patients who screened negative on M-CHAT are shown in Table 5. No significant gender differences were observed among ASD, GDD, and DLD groups (*P* = 0.104). The mean age at M-CHAT and CVAQ was 39.2 months (range, 31.5–45.4), 39.4 months (range, 29.8–46.4), and 34.3 months (range, 23.6–43.5) for patients with ASD, GDD, and DLD, respectively (*P* = 0.170).

Table 5
Comparison of demographic and clinical characteristics within negative M-CHAT screen group

	ASD (n = 4)	**GDD** (n = 4)	**DLD** (n = 22)	***P* value**
Gender (Male)	4 (100)[a]	4 (100)[a]	13 (59.1)[a]	0.104
Age (months) at M-CHAT and CVAQ, mean (range)	39.2 (31.5–45.4)	39.4 (29.8–46.4)	34.3 (23.6 – 43.5)	0.170
Number of failed tasks related to the ventral visual stream, mean (range)	0.3 (0–1)	0.3 (0–1)	0.9 (0–3)	0.149
Number of failed tasks related to the dorsal visual stream, mean (range)	0.5 (0–2)	0 (0)	0.1 (0–1)	0.437

M-CHAT, Modified Checklist for Autism in Toddlers; ASD, autism spectrum disorder; GDD, global developmental delay; DLD; developmental language delay; CVAQ, Cognitive Visual Assessment Questionnaire

[a]Values are percentages (%).

Regarding the ventral processing stream, patients with ASD failed to perform a mean of 0.3 tasks (range, 0–1), while those with GDD or DLD failed to execute a mean of 0.3 tasks (range, 0–1) and 0.9 tasks (range, 0–3), respectively. The DLD group had a higher number of failed tasks related to the ventral visual stream pathway compared to the ASD or GDD group, although no statistically significant difference was observed (*P* = 0.149).

Regarding the dorsal processing stream, patients with ASD failed to achieve a mean of 0.5 tasks (range, 0–2), while those with GDD or DLD failed to perform a mean of 0 tasks (range, 0) and 0.1 tasks (range, 0–1), respectively. The ASD group had a higher number of failed tasks related to the dorsal visual stream pathway than the GDD or DLD group, although the differences were not statistically significant (*P* = 0.437).

Patients were subdivided into two groups: ASD group (n = 4) and GDD or DLD group (n = 26). No significant difference in gender distribution or mean age at M-CHAT and CVAQ were observed between these two groups. The mean number of failed tasks related to the ventral stream pathway was 0.3 tasks and 0.8 tasks in the ASD group and GDD or DLD group, respectively, which showed no statistically significant difference ($P = 0.238$). In addition, the mean number of failed tasks related to the dorsal stream pathway was 0.5 tasks and 0.1 tasks in the ASD group and GDD or DLD group, respectively ($P = 0.069$).

[Table 5 TO BE PLACED HERE]

Discussion

This is a large-scale study of children with ASD and other developmental delays. ASD is a common neurodevelopmental disorder with a prevalence of approximately 1–3% [25–27]. Identification of individuals with ASD during early development is critical because it leads to timely and proper intervention and better functional outcomes for affected children and their families [28, 29]. However, diagnostic difficulties may arise in certain circumstances due to heterogeneity of the disorder and its variable onset and presentation [30]. In addition, similar features between individuals with ASD and other developmental delays may complicate differential diagnosis in children [30]. Impairment in attention orienting has been associated with ASD [13–16], so we tried to delineate the feasibility of CVAQ as a screening tool for differentiating ASD from other developmental delays. Importantly, children who failed M-CHAT and were finally diagnosed with ASD have specific impairment in dorsal stream function.

The M-CHAT is currently one of the most widely used ASD screening instruments that can be readily performed in primary care and clinical settings [22, 29, 31]. In our study, children who screened positive on M-CHAT were more likely to receive a diagnosis of ASD compared to children who screened negative. Previous studies reported that the sensitivity, specificity, and positive predictive value of M-CHAT in screening for ASD were 70–92%, 27–98%, and 5.8–76%, respectively, depending on the age group and associated risk factors [32, 33]. In accordance with previous studies, our results demonstrated that the sensitivity, specificity, and positive predictive value of M-CHAT in detecting children with ASD were 88.2%, 32.1%, and 35.3%, respectively.

In our analysis, the accuracy of CVAQ in detecting ASD varied according to age group, and the sensitivity of CVAQ in children aged 36–48 months was 63.6%. Sensitivity increased to 83.3% and 94.1% in children aged 14.1 – <24 months and 24 – <36 months, respectively. Conversely, the specificity was low for the 14.1 – <24 months age group, at 5.9%, but it improved to 14.7% and 46.7% for the two older age groups. Toh et al. [34] addressed the low sensitivity (17.9%) of M-CHAT in detecting ASD in the 15 – <21 months age group; it improved to 54.5% and 63.6% in the 21 – <27 months and 27–36 months age groups, respectively, and the specificity was above 99% for all three age groups. Because earlier diagnosis of ASD allows earlier effective intervention, it is important to screen children at an early age to detect those with early features of ASD and yield better functional outcomes [30, 34]. Our data revealed that CVAQ is a useful alternative screening tool for differentiating ASD from other developmental delays among toddlers. The CVAQ test has better sensitivity than the M-CHAT in young children.

Visual processing problems have been considered an underlying factor for cognitive impairments in ASD [35]. At the earlier stages of visual perception, neurons in the primary visual cortex process local stimuli to provide spatially limited signal for perception [36]. At later stages of visual perception, since the classical receptive fields are small, information that reaches the primary visual cortex must be integrated to enable global perception of both the dorsal and ventral visual streams [37]. The ventral stream is implicated in both object and face recognition, while the dorsal stream is related to the spatial location of objects and their relation to each other [23]. Among children who screened negative on M-CHAT, patients with ASD failed more in tasks related to the dorsal stream pathway, whereas those with DLD failed more tasks related to the ventral stream pathway. These findings are consistent with previous studies that addressed specific impairments in dorsal stream functioning in autistic individuals [23, 38]. This phenomenon is in accordance with the evidence that autistic children have enhanced ability to find embedded targets in large figures or reproduce unsegmented block designs, while deficits in motor performance, such as clumsiness or lack of coordination, are common features of autism [23, 35].

Increasing efforts to identify children with ASD at the early stages emanate from the understanding that timely intervention in ASD improves a patient’s long-term developmental and functional outcomes [8, 30]. According to Mitchell et al. [30], specific profiles of behavioral markers in the social domain by 12 months and in the communication domain by 18 months, along with additional atypical motor behaviors, may help clinicians to distinguish ASD from other developmental delays among infants. Zhang et al. [39] demonstrated that diffusion tensor imaging parameters of the arcuate fasciculus, an important language-related white matter tract, are useful for differentiating ASD with language delay from DLD in toddlers. The current study indicates that when coupled with clinical observation and judgement, CVAQ provides an easily accessible and effective method to assist in clinical diagnosis and management in the early stages of ASD and improve prognosis.

Our study has several limitations. Firstly, patient samples were from a single referral center, which likely affected the predictability of measures and influenced the lack of statistical significance. Secondly, due to the retrospective nature of this study, we were constrained by information from the medical records and individual recall. However, this study provides preliminary data on the utility and efficacy of CVAQ in detecting autistic children for larger prospective studies or collaborative trials in the future.

Conclusions

Early identification of children with ASD and timely intervention are essential to improve functional outcomes for affected children and their families. However, similar features between ASD and other developmental delays may impede timely diagnosis. Among children who failed M-CHAT, individuals with ASD had specific impairment in dorsal stream functioning. In addition, CVAQ showed improved sensitivity for detecting ASD in toddlers. When coupled with clinical observation and judgement, CVAQ is an easily accessible and useful screening tool for differentiating ASD from other developmental delays in young children.

Abbreviations

ASD
Autism spectrum disorders; CVAQ:Cognitive Visual Assessment Questionnaire; M-CHAT:Modified Checklist for Autism in Toddlers; GDD:global developmental delay; DLD:developmental language delay

Declarations

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Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Catholic Medical Center (IRB UC20RASI0035). Informed consent was waived due to the retrospective design of the study.

Consent to publish

Not applicable.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that there are no conflicts of interest.

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Authors' contributions

The manuscript was written by JKS and EGP. Data collection and analysis was conducted by JKS, YHK, and EGP. EGP supervised all aspects of the analysis and manuscript preparation. All authors have read and approved the final manuscript.

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