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Original Article

Correlation Between Binocular Vision and Children's Temperament

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Purpose: The purpose of this study is to investigate the relationship between temperament and binocular vision in kindergarten age children.
Methods: A total of 32 healthy children aged 5 to 6 participated in the study. Binocular examination, visual-motor integration test, questionnaire about children's health, nutrition, upbringing, amount of sleep, leisure activities, and 3C device use, and temperament assessment battery for children were administered.
Results: Binocular examination results indicated that all participants had refractive errors. Eight and 10 children had poor visual acuity, but only one wore corrective lenses. Most children had normal pupillary response, color vision, pursuit, fixation, and saccades, but poor stereoacuity and accommodation. Moreover, cover-uncover test results revealed phoria (eso 9.4%; exo 46.9%) in more than half of the children. Processed foods and gender were the modulating factors for activity level. Modulating factors for the temperament dimension of adaptability were habitual eye and near visual acuity. Those for approach included habitual eye and fruit. Those for quality of mood were processed foods, irritable physique, and sleep. Those for distractibility included myopia, pupil response, and phoria. Finally, that for persistence was processed foods.
Conclusion: Some of these modulators may be due to the requirement for attention and adaptability during the learning process. It should be mentioned that binocular vision, especially habitual eye, near visual acuity, phoria (exo and exo), and accommodation may play major roles in children's temperament and influence their learning and social skills.

Keywords: Temperament, Binocular vision, Kindergarten age children, Activity level, Distractibility, Approach, Adaptability, Persistence, Quality of mood

1. Introduction

Since vision plays a major role in analyzing inward information and outward movement, patients with poor eyesight or abnormal visual function might have problems walking, reading, and performing daily life tasks, as well as poor sense of space and orientation[1-3]. It is highly probable that binocular vision impacts on emotional development and temperament, resulting in inattention, complaining, or sluggish adaptation4-5. Moreover, it needs to be emphasized that the percentiles of abnormal visual function in Taiwan are much higher

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than in other countries[6-7].

Temperament is neither good nor bad. It is an inherent characteristic and represents one's personality and disposition[8-9]. Previous studies have shown that temperament varies with environmental change, diet and nutrition[10-16], disease and drug use, neuro-anomalies, cognitive and attention disabilities[17-21], amount of sleep, sedentary lifestyle[22-26], and refractive errors or visual function anomalies[26-30].

2. Methods

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki for medical research involving human subjects (CS2-17087). Three experienced and licensed optometrists were responsible for conducting comprehensive eye examinations. Thirty-two healthy kindergarten age children were enrolled. Children with cognitive, sensory, or neuro-psychological impairment were excluded. Although the neuro-visual system may not be fully developed, visual perception improves rapidly from 4 to 6 years of age, during which there is good visual acuity of 1.0 and fairly good stereoscopic vision, so that children at this age can judge size and shape during the performance of different tasks. The following examinations and tools were administered:

2.1 Cover-uncover test

Cover-uncover test was performed to screen for tropia and phoria under habitual correction, using prism bar to quantify the deviation. In the presence of uncorrected refractive error, large anomalies may occur.

2.2 Pupillary response

A pen light was used to observe pupil size and response directly and indirectly. Expected findings were pupils of equal size in addition to consecutive contraction without lag. If size or speed is inconsistent, researchers might suspect obstacles in the visual-cortex pathway.

2.3 Visual acuity

Video display terminal (VDT) (far) and Lea Numbers (40 cm) test were used. Measurements of both near and far visual acuity were performed under corrected and habitual conditions, monocularly and binocularly. Since all children in this study ranged from 5 to 6 years old, abnormal visual acuity was defined as less than 0.8 and dominant eye was documented.

2.4 Eye movement (Ocular motor)

Eye movement includes fixation, pursuit, and saccade. Pursuit refers to the tracking ability and saccade to two-stage jumping movement of both eyes. After the age of 4, saccadic velocity begins to decrease but accuracy increases. Reading is related to binocular gaze and concentration. Eye movements were expected to be smooth, fast, and accurate. A dedicated optotype of eye movements was applied.

2.5 Stereopsis

The expected value of stereopsis (depth perception) in this study group was 200 second of arc or better. Random dot test with polarized glasses was utilized to measure stereoscopic ability.

2.6 Color vision

Ishihara color vision test was performed to understand types of color blindness (protanopia, deuteranopia, and tritanopia) and color deficiencies (protanomaly, deuteranomaly, and tritanomaly).

2.7 Near Point of Accommodation (NPA)

Donder's push-up method was performed monocularly three times. The expected value according to Hofstetter's formula was D= 15 - (age/4).

2.8 Visual-Motor Integration (VMI)

The Beery-Buktenica Development Test of Visual-Motor Integration (VMI)[31] is a non-verbal assessment of the extent to which individuals can integrate visual and motor abilities. Considering the age and attention span of the subjects, researchers selected the simplified version for evaluation.

2.9 Temperament Assessment Battery for Children (TABC)

Temperament Assessment Battery for Children (TABC) is the main tool for evaluating temperament

in children. It includes six dimensions: Activity, Distractibility, Persistence, Approach, Adaptability, and Quality of mood.[32]

2.10 Questionnaire

A self-constructed questionnaire was compiled that focused on children's health; nutrition; upbringing; amount of sleep; leisure activities; TV, mobile phone, and iPAD use; and TABC scores. Parents and teachers were asked to fill out this questionnaire before binocular examination.

3. Results

Thirty-nine parents signed a consent form allowing their child to participate in this study. One child was undergoing patching therapy, five children did not finish binocular vision examination, and one child was absent on examination day. Finally, data was acquired from 32 subjects.

There were 14 boys (43.8%) and 18 girls (56.3%). Only three participants had standard body mass index (BMI) (18.5-24 kg/m^2, Health Promotion Administration, Ministry of Health and Welfare, 2018). For most participants, BMI was below the standard (n=28, 87.5%). Five participants were born premature without detected or diagnosed developmental impairment. High ratios of allergies (n=18, 56.3%) and sleep insufficiency (n=23, 71.9% under 8-9 hours/day) were reported. Most were the eldest child (n=25, 78.1%) and 10 (31.3%) were singleton. It is worth noting that only four parents indicated that their child had vision problems, which was very different from the results of binocular examination in this study. This indicates that parents do not recognize their children's vison problems very well.

All participants suffered from sleep insufficiency. In addition to doing their homework, over half of the participants (n =17, 53.1%) used mobile phone or watched TV (n =26, 81.3%) 1 to 2 hours a day. Four participants spent long periods of time on 3C devices.

To a certain extent, eating habits might be bound up with children's temperament. From 90 to 97% of participants ate non-staple foods, vegetables, and fruits every day. A high proportion of participants had one to two servings of sweet drinks (n=23, 71.9%, one serving =200c.c) and Western food (n=26, 81.3%). About half of the participants ate red meat (n =18, 56.3%), fried foods (n =14, 43.7%), or processed foods (n =13, 40.6%) every day.

3.1 Temperament

TABC was filled out by parents and teachers. Scores between 1.00 and 4.67 were considered medium to low and scores between 4.68 and 7.00 were considered high. On t test analysis, there were no significant differences between parents' and teachers' responses on TABC. Therefore, TABC data was combined for further analysis.

Over half of the participants had high Adaptability (n=29, 90.6%) and Persistence (n=21, 65.6%) scores and medium to low Activity (n=28, 87.5%), Approach (n=20, 62.5%), Quality of mood (n=26, 81.3%), and Distractibility (n=24, 75.0%) scores (Table 1). Each

Table 1. Temperament Assessment Battery for Children (TABC)

Temperament dimension	Min	Max	Mean	SD	High N	High %	Medium to low N	Medium to low %
Parents and Teachers								
Activity	2.00	5.25	3.53	0.85	28	87.5	4	12.5
Adaptability	3.94	6.13	5.27	0.53	3	9.4	29	90.6
Approach	3.38	6.38	4.56	0.74	20	62.5	12	37.5
Quality of mood	2.75	5.38	3.95	0.66	26	81.3	6	18.8
Distractibility	2.44	5.25	3.89	0.74	24	75.0	8	25.0
Persistence	3.88	5.44	4.79	0.38	11	34.4	21	65.6

Table 2. Results of binocular vision examination

Dominance	n	%	Eye frame	n	%	Habitual D VA	n	%	Habitual N VA	n	%
Dextrocu-larity	19	59.4	Yes	1	3.1	Normal	24	75.0	Normal	22	68.8
Sinistrocu-larity	13	40.6	No	31	96.9	Abnormal	8	25.0	Abnormal	10	31.3
Myopia	**n**	**%**	**Hyperopia**	**n**	**%**	**Astigmatism**	**n**	**%**	**Anisome-tropia**	**n**	**%**
No	19	59.4	No	20	62.5	No	5	15.6	No	22	68.8
Yes	13	40.6	Yes	12	37.5	Yes	27	84.4	Yes	10	31.3
Fixation	**n**	**%**	**Saccade**	**n**	**%**	**Pursuit**	**n**	**%**	**Cover-Uncover**	**n**	**%**
Normal	30	93.8	Normal	31	96.9	Normal	32	100.0	Ortho	14	43.8
Abnormal	2	6.3	Abnormal	1	3.1	Abnormal	0	0.0	Tropia♁	18	56.3
Stereopsis	**n**	**%**	**Pupillary**	**n**	**%**	**Hirschberg**	**n**	**%**	**Color vision**	**n**	**%**
Normal	27	84.4	Normal	31	96.9	Normal	32	100.0	Normal	31	96.9
Abnormal	5	15.6	Abnormal	1	3.1	Abnormal	0	0.0	Abnormal	1	3.1
OD Accomo-dation	**n**	**%**	**OS Accomo-dation**	**n**	**%**	**OU Accomo-dation**	**n**	**%**	**VMI**	**n**	**%**
Normal	22	68.8	Normal	23	71.9	Normal	19	59.4	>average	17	53.1
Abnormal	10	31.2	Abnormal	9	28.1	Abnormal	13	40.6	<average	15	46.9

♁ exo n=3, 9.4%; exo n=15, 46.9%

participant was classified based on six personality types: widespread, social, hyperactive, focused, easygoing, and quiet. According to the TABC scores, 53.1% (n=17) of participants were of widespread type, 21.9% (n=7) were of hyperactive type, 21.9% (n=7) were of quiet type, and only one (3.1%) was of social type. None of the participants were of focused or easygoing type.

3.2 Binocular vision

About 40% of participants had refractive errors. Moreover, 40.6% (n=13) demonstrated myopia and 37.5% (n=12) demonstrated hyperopia. Up to 84.4% (n=27) had astigmatism and 31.3% (n=10) had anisometropia. Eight (far) and 10 (near) children had poor visual acuity, but only one child had been prescribed corrective lenses. Moreover, 59.4% (n=19) of subjects showed dextrocularity and 40.6% (n=13) sinistrocularity. Most children had normal pupillary response (n=31, 96.9%), normal color vision (n=31, 96.9%), normal pursuit (n=32, 100%), normal fixation (n=30, 93.8%), and normal saccades (n=31, 96.9%). However, some showed poor stereoacuity (n=5, 15.6%) and poor accommodation (n=13, 40.6%). Moreover, cover-uncover test results revealed phoria in over half of the subjects (eso n=3, 9.4%; exo n=15, 46.9%).

All participants had normal VMI score (M= 61.78%, 13% to 94.2%), but only half (n=17, 53.1%) scored higher than the standardized mean. The remaining participants demonstrated lower than average scores but within normal range. In this study, VMI score was not correlated with participants' background or daily life but was significantly correlated with eating habits, including red meat (r=-0.465, p=0.007), Western food (r=-0.429, p=0.014), fried foods (r=-0.373, p=0.36), and fruit (r=-0.582, p=0.000). Moreover, Adaptive dimension explains

Table 3. Linear regression analysis of predicate variables for temperament

Temperament	Predicate variance	R	R square	Adjusted R square	Estimated SE
Activity	Gender	.496	.246	.221	.75054
	Processed foods	.657	.432	.413	.65149
Adaptability	Dominant eye	.467	.218	.192	.47854
	Near VA	.572	.327	.281	.45151
Approach	Fruit	.381	.145	.117	.69619
	Dominant eye	.397	.158	.130	.69100
Quality of mood	Allergies	.420	.177	.149	.61123
	Amount of sleep	.411	.169	.141	.61414
	Processed foods	.514	.264	.240	.57777
Distractibility	Gender	.397	.158	.130	.69034
	Mobile phone use	.389	.151	.123	.69315
	Amount of sleep	.513	.264	.213	.65654
	Near VA	.528	.279	.255	.63873
	Binocular Accommodation	.674	.454	.416	.56534
	Cover-Uncover	.747	.558	.510	.51778
Persistence	Processed foods	.397	.158	.130	.35509

the up to 11.4% variance in VMI (r=-0.354, p=0.047; adjusted R^2=.114). (R squared is the proportion of the variance in the dependent variable that is predictable from the independent variables).

VMI was also associated with dominant eye (r=0.442, p=0.011), cover-uncover test (r=0.559, p=0.000), and NPA (r=0.650, p=0.000). The latter two might predict VMI performance and explain the up to 45.0% variance (R =0.709, R^2=0.503, Adjusted R^2=0.450).

3.3 Analyses of temperament-related variances

3.3.1 Relationships between temperament and background data

Taking the six temperament dimensions as dependent variables, every background variable was independent. Results of linear regression analysis indicated that Activity (R =0.496, R^2=0.246, Adjusted R^2=0.221) and Distractibility (R =0.397, R^2=0.158, Adjusted R^2=0.130) are explained by gender, while Quality of mood is explained by allergies (R =0.420, R^2=0.177, Adjusted R^2=0.149). Other temperament dimensions showed no significant association with background data.

3.3.2 Relationships between temperament and daily life

Pearson correlation and linear regression analysis indicated that Activity, Adaptability, Approach, and Persistence are not related to participants' daily life. It is worth noting that amount of sleep is significantly associated with Quality of mood (r=-0.411, p=0.019) and Distractibility (r=-0.378, p=0.026). Distractibility could be explained not only by amount of sleep but also by mobile phone use (R =0.513, R^2=0.264, Adjusted R^2=0.213).

3.3.3 Relationships between temperament and eating habits

In terms of eating habits, processed foods played an important role in participants' temperament and were significantly correlated with Activity (r=0.657,

p=0.000), Quality of mood (r=0.514, p=0.030), and Persistence (r=-0.397, p=0.024). It is interesting that eating fruit contributed to Distractibility (r=-0.381, p=0.032).

3.3.4 Relationships between temperament and binocular vision

The main purpose of this study was to investigate the relationships between children's temperament and binocular vision. Results indicated that dominant eye, near visual acuity, NPA, pupillary response, and cover-uncover test were strongly associated with participants' temperament. Adaptability could be explained by dominant eye and near visual acuity (R =0.572, R^2=0.327, Adjusted R^2=0.281). Distractibility was correlated with dominant eye (r=0.397, p=0.024). The most predictable temperament dimension was Distractibility, which could be explained by near visual acuity, NPA, pupillary response, and cover-uncover test (R =0.747, R^2=0.558, Adjusted R^2=0.510).

To integrate the above relationships, all variables including those associated with background, daily life, eating habits, and binocular vision were considered simultaneously. Activity could be explained by gender and processed foods (R =0.657, R^2=0.432, Adjusted R^2=0.413). Adaptability could be explained by dominant eye and near visual acuity (R =0.572, R^2=0.327, Adjusted R^2=0.281). Approach could be explained by dominant eye and fruit (R =0.397, R^2=0.158, Adjust R^2=0.130). Quality of mood could be explained by allergies, amount of sleep, and processed foods (R =0.514, R^2=0.264, Adjusted R^2=0.240). Distractibility was correlated with gender, mobile phone use, amount of sleep, near visual acuity, NPA, and cover-uncover test (R =0.747, R^2=0.558, Adjusted R^2=0.510). Finally, persistence was correlated with processed foods (R =0.397, R^2=0.158, Adjusted R^2=0.130).

4. Conclusion and Discussion

To sum up, along with increases in consumption of fast foods and exquisite comestibles, the use of sugar and artificial products has become ubiquitous among young children. The roles of allergies[33] and digital device use[34] also need to be considered in the development of temperament in this age group.

Comparing the four participants who spent long periods of time using 3C devices, we discovered that more 3C device use and less sleep greatly impact on children's temperament, particularly in terms of Distractibility and Quality of mood. These results were similar to the findings of white light and blue light research[35-36].

Gender was an obvious factor in this study. Gender bias[37] exists, especially in Asia. There are well-replicated self-reported gender differences between men and women in terms of higher- and lower-order dimensions of personality. Processed foods increased risk in terms of Adaptability, not only impacting on physical health, but also on mental health.

The results of binocular function examination showed that 70 to 75% of participants had normal distance visual acuity and near visual acuity and up to 40% had refractive errors. However, only one child wore corrective lenses, which meant that 20% to 30% of children had not received comprehensive treatment. According to the Health Promotion Administration of the Ministry of Health and Welfare, myopia rate has increased from 7.1% to 9%[38] among preschool age children, excluding hyperopia and astigmatism.

Some participants demonstrated significantly reduced stereopsis, NPA, and VMI performance, in addition to phoria and tropia. Previous studies have demonstrated that in addition to visual acuity, there are correlations among binocular vergence, accommodation, phoria, stereopsis, myopia, and even VMI performance[2, 39]. Sortor & Kulp[40] and Kulp[41] indicated that VMI scores are correlated with math and reading abilities among children aged 7 to 9 and reading corresponds to binocular vision. In this study, VMI performance was associated with binocular visual function, including dominant eye, near visual acuity, cover and uncover test, and NPA. The latter two might predict VMI performance and explain the up to 45.0% variance in VMI. Among some participants, consumption of red meat, Western food, fried foods, and fruit was also associated with VMI. Furthermore, there was a correlation between temperament and Distractibility, which was associated with near visual acuity, NPA, and cover-uncover test. This was likely due to lack of comprehensive refractive correction, which might affect binocular

vision, attentiveness, reading accuracy, and reading effectiveness[22-26, 41].

Another novel finding is that the dominant eye correlated with Adaptability and Approach, similar to the results of a study by Maples[41]. We concluded that dominant eye and hand influence children's reading, comprehension, visual-motor skills, and even academic performance.

Since legislation of optometry licensing in Taiwan on December 18, 2015, optometrists have officially become involved in binocular vision examination and clinical treatment. Optometrists should pay attention not only to factors related to clinical examination and prescription of corrective lenses, but also to BMI, eating habits, quality of sleep, and amount of time spent on sedentary activities. In addition, children's behaviors, temperament, and learning performance need to be emphasized and their correlation with vision needs to be better understood.

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