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DEVELOPMENT AND RELATIONSHIP BETWEEN PERFORMANCE AND THE DRAWING PROCESS ON THE BENDER-GESTALT TEST AS ANALYZED USING THE DIGITAL PEN

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Abstract

This study investigated the developmental changes and characteristics in children's Bender-Gestalt Test, including not only the finished drawing (size, the number of strokes, and their preciseness in copying [i.e., total scores]), but also the drawing process (duration, speed, and pressure). Developmental changes and the relationship between the method of drawing and the Bender-Gestalt Test score were also examined. Our research utilized a high-technology interface 'digital pen' (Anoto DP201) and paper, which converts handwritten analog information created by the pen and paper into digital data and stores it in its built-in memory. Seventy 4-to 6-year-old Japanese preschoolers (34 boys and 36 girls) were asked to copy the Bender-Gestalt Test figures with the digital pen. Results showed the developmental changes and the relationship between the performance of copying the figures and drawing process; the older children drew smaller figures more slowly with stronger pressure, and that the children who drew figures more slowly displayed better Bender-Gestalt Test total score. Sex differences were found in total stroke length and average pressure; girls drew smaller figures with stronger pressure than boys. This study showed that the drawing tests provided more valuable information by analyzing *how* the participants drew in addition to *what* they drew.

Keywords: Bender-Gestalt Test, Japanese Preschoolers, Drawing Process, Digital pen

1. Introduction and Purpose

The Bender Visual-Motor Gestalt test (BGT; Bender, 1938) is one of the most versatile psychological tests to evaluate visual-motor maturity and nonverbal intelligence, and to screen for developmental disorders, neuropsychological dysfunction, or brain damage. This test is also used as a standard projective technique in personality assessment. Latest surveys ranked the

BGT as the most widely used by clinical and school psychologists for all age groups (Archer & Newsom, 2000; Piotrowski, 1995; Stinnett, at al., 1994). The advantage of the test is its simple procedure; it only requires examinees to copy nine geometric figures on a sheet of paper. For children, this test is primarily used for clinical diagnosis and the measurement of social-emotional and perceptual-motor deficits (see Kennedy, Faust, Willis, &Piotrowski, 1994; Stinnett, *et al.*, 1994). Previous research has also investigated the relationship between the BGT and other motor-visual-perceptual measures (Shapiro & Simpson, 1994; Brannigan& Decker, 2003) or compared the BGT scores between typical and special needs samples (Volker et al, 2010).

As we have described, the BGT is a widely used, multipurpose test; however, previous studies have investigated the finished drawings of BGT figures, and none has examined the process of making the drawings, namely, how examinees copy the figures. As the BGT is a motor and visual–perceptual test, more attention should be given to the drawing process, which reflects motor skills involved in controlling drawing speed and pressure at the beginning and the end of a stroke, in addition to the visual and perceptual coordination skills such as spatial understanding in constructing each stroke in the appropriate place. These dynamic data provide rich information for both clinicians and researchers.

Although some studies have investigated the process of children's drawings, particularly the order of drawing in human figures and geometrical figures (Goodnow& Levine, 1973; Thomas & Tsalimi, 1988), certain technical difficulties remain to be solved. First, videotaping drawing activities to score drawing process can make the participants nervous. Moreover, it is almost impossible to precisely code the drawing process of children from the recorded video image. Therefore, we adopted the digital pen and line-analyzing software (Elian, n.d; Wallon et al, 2000) to solve these problems.

In our study, the digital pen was used with Anoto paper and Elian software (Figure 1). The digital pen is a high-technology device that converts handwritten analog information using a pen and a paper into digital data stored in the pen's built-in memory. The stored information can be easily transferred to a PC or other IT devices via a Bluetooth or a USB interface over networks, and used in various applications. The Anoto paper is spotted with small points on the surface. The points are placed according to four positions in an invisible pattern (up–down and left–right).

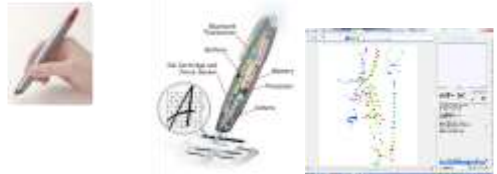

Figure 1: The Anoto system (a digital pen, an Anoto paper, and Elian software)

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Elian software, distributed by Seldage, translates records on the dynamics of each gesture, reproducing the drawing process on the screen. It also provides an automatic analysis on parameters such as stroke order, stroke directions, speeds (average, maximum), number of strokes, durations (global, effective drawing and pauses), and pressure as well as the size and disposition of figures. The movement can be reproduced *ad libitum* and stopped at any time and examined in various ways. The drawing process can be precisely visualized with colors, dynamically, or by step.

Previous research has performed computerized analysis of handwriting process, but focused only on pauses, speed (calculated by total time divided by numbers of written letters), or spatial aspects (Rosenblum et al, 2003). Moreover, few studies have investigated the process of taking the psychological drawing test via computerized analysis (Wallon & Mesmin, 2009). Wallon and Mesmin (2009) collected data on Rey Complex Figures A and B (Rey, 1942), standardized the dynamic data extracted from Elian software, and established an automatic analysis and diagnosis of the pathological cases. Their accomplishment serves as the leading work for our BGT research.

This study examined children's BGT, not only the finished drawing (size, the number of strokes, and their preciseness in copying (i.e., total scores), but also the drawing process (duration, speed, and pressure) and describes their developmental changes. The relationship between the method of drawing and the BGT score was also examined. We hypothesized that developmental changes will be found in their drawing process, and there will be the association between the BGT score and their drawing process.

2. Method

2.1 Participants

A total of 76 children aged 4- to 6-yr.-olds were recruited from a nursery school in Kyoto, Japan. The data of six participants could not be used because of experimental errors or children failing to complete the entire session. The remaining 70 preschoolers (34 boys and 36 girls; 4 yr.: 21; 5 yr.:21; 6 yr.: 28) comprised the final sample. All the participants were from middle or higher income families and had no medical or psychological complications. This research was conducted in accordance with APA's Ethical Principles of Psychologists and Code of Conduct in the treatment of participants.

2.2 Procedures

The experiments were conducted in a room of the nursery school. The participant was seated across the table from the experimenter.

Bender-Gestalt Test

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The BGT contains nine figures, each on its own 3 × 5 card. The participant is shown each figure and asked to copy it onto a piece of blank paper with the digital pen. Each test took approximately ten min.

Scoring

The BGT results were scored with two-way analysis, that is, Koppitz Scoring System and Elian Analysis.

Koppitz Scoring System

Two well-trained graduate students scored the BGT based on the Koppitz version of the scoring system (scored from 0 to 3, according to the preciseness in copying). In the case of disagreement, the two scorers discussed the evaluation until reaching agreement.

Elian Analysis

The following five drawing styles were analyzed by Elian software: (1) the number of strokes, (2) duration (the total time spent to copy the nine figures), (3) the total length (of strokes in millimeters), (4) speed (the average drawing speed (millimeter/second)), and (5) pressure.

3. RESULTS

To examine developmental changes in drawing styles and the BGT score, two-way factorial analysis of variance without replication was conducted for each age (4-, 5-, and 6- yr.-old), with the drawing styles (i.e., the number of strokes, duration, the total length, speed, and pressure) and the BGT score as the between-group factors. Bonferroni tests were used for post-hoc analysis, and correlations between the drawing styles and the BGT score were examined.

Developmental changes in drawing styles (Table 1)

The number of strokes

There were no significant main effects of age (F (2, 67)=2.14, n.s.) in the number of strokes. This result indicated that children in all age groups copied all nine figures without omission.

Duration, Total Length, Speed, and Pressure

There were no significant main effects of age (F (2, 67)=0.41, n.s.) in the duration time. Total length exhibited a significant main effect of age (F(2, 67)=14.38, p<.01). The post-hoc analysis revealed significant differences between 4 and 5 (p<.01) and between 4- and 6- yr.-olds (p<.01). Children aged 5 and 6 drew smaller figures than 4- yr.-olds. The average speed of drawing exhibited a significant main effect of age (F(2, 67)=4.86, p<.05). The post-hoc analysis revealed significant differences between 4 and 5(p<.05) and between 4- and 6-yr.-olds (p<.05). Four-yr.-old children copied the figures faster than5- and 6-yr.-olds. The average pressure of drawing exhibited a significant main effect of age (F(2, 67)= 6.72, p<.01). The post-hoc analysis revealed significant differences between 4 and 5(p<.05) and between 4- and 6-yr.-olds(p<.01). Five- and six- yr.-old children copied the figures with stronger pressure than 4-yr.-olds.

Developmental Change in the BGT score (Table 1)

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The BGT score exhibited a significant main effect of age ($F(2, 67)= 41.95$, $p<.01$). The post-hoc analysis revealed significant differences between 4 and 5($p<.01$), between 4 and 6 ($p<.01$), and between 5- and 6- yr.-olds ($p<.05$). The BGT total score increased with age.

Correlations between Drawing Styles and the BGT Score

Correlation analysis was performed between the drawing styles (number of strokes, duration, total length, speed, and pressure), the BGT score, and age in months (Table 2), revealing significant correlations among the drawing styles, the BGT score, and age. Therefore, the partial correlation coefficient was calculated by controlling the effect of age (Table 3). Results revealed significant correlations between BGT score and drawing speed, indicating that the more slowly the children drew, the more accurately they could copy the figures.

Table 1 Developmental changes in drawing styles
(the number of strokes, duration, the total length, speed, and pressure) and the BGT score

	F (2, 67)	4yers-old (*n*=21) *M*(*SD*)	5years-old (*n*=21) *M*(*SD*)	6years-old (*n*=28) *M*(*SD*)
number of strokes	2.14	88.81 (32.64)	94.33 (20.39)	102.57 (16.39)
duration	0.41	372.52 (144.93)	371.81 (181.41)	341.61 (89.94)
total length	14.38**	3052.24 (1262.44)	1718.67 (548.05)	1904.21 (737.56)
speed	4.86*	23.05 (15.65)	14.00 (7.16)	15.75 (5.75)
pressure	6.72**	83.33 (21.36)	99.29 (18.02)	101.46 (15.30)
BGT score	41.95**	13.33 (5.07)	7.14 (2.73)	4.43 (2.03)

**$p<.01$ *$p<.05$

Table 2 Pearson correlation coefficient between the drawing styles (number of strokes, duration, total length, speed, and pressure), the BGT score, and age in months.

	number of strokes	total length	speed	pressure	BGTscore	Age
duration	.411**	.232	-.382**	-.047	-.008	-.082
number of strokes	-	-.053	-.321**	-.079	-.207	.254*
total length	-	-	.581**	-.251*	.424**	-.440**
speed	-	-	-	-.178	.425**	-.323**
pressure	-	-	-	-	-.278*	.321**
BGTscore	-	-	-	-	-	-.769**

**$p<.01$ *$p<.05$

Table 3: The partial correlation coefficient between the drawing styles
(number of strokes, duration, total length, speed, and pressure)

Asia Pacific Institute of Advanced Research (APIAR) DOI : 10.25275/apjabssv4i2ss3

and the BGT score, calculated by controlling the effect of age.

	number of strokes	total length	speed	pressure	BGTscore
duration	.448**	.219	-.430**	-.029	-.112
number of strokes	-	.067	-.261*	-.175	-.020
total length	-	-	.517**	-.129	.150
speed	-	-	-	-.083	.293*
pressure	-	-	-	-	-.052

**p<.01 *p<.05

Sex Differences (Table 4)

Sex differences were found in total length ($t(68)=-2.76$, $p<.01$) and average pressure ($t(68)=2.76$, $p<.01$). Other parameters, including the BGT score, exhibited no differences. Girls drew smaller figures with stronger pressure than boys.

Table 4 Sex differences in drawing styles
(the number of strokes, duration, the total length, speed, and pressure) and the BGT score.

	duration M(SD)	number of strokes M(SD)	total length M(SD)	speed M(SD)	pressure M(SD)	BGT score M(SD)	Age M(SD)
Boys (n=34)	372.29 (123.43)	94.7 (22.3)	2530.97 (1075.43)	18.65 (10.81)	89.03 (22.57)	8.76 (5.75)	65.53 (11.11)
Girls (n=36)	348.28 (151.14)	97.2 (25.5)	1873.72 (916.74)	16.25 (10.49)	101.36 (14.02)	7.11 (4.15)	66.97 (10.49)
t score	0.73	-0.44	2.76**	0.94	-2.76**	1.38	-0.56

4. Discussion

Our study revealed developmental changes in drawing styles (the total length, speed, and pressure). As the children grew older, they drew smaller figures more slowly with stronger pressure. This phenomenon can be explained by their fine-motor development, including behavioral self-regulation and cognitive development based on the neurological maturity. Fine-motor skills become more sophisticated around the age of 5 to 6yr., which can be seen in, for example, copying numbers and simple words (Haywood & Getchell, 2009). Moreover, the frontal lobes, which affect self-regulation, rapidly grow at the age of 4 to 7 yr. (Hudspeth & Pribram, 1990). Previous research (Levy, 1980) asked children to slowly draw a line as a measure of motor inhibition, and demonstrated clear development between 4 and 6 yr. of age. In our

Asia Pacific Institute of Advanced Research (APIAR) DOI : 10.25275/apjabssv4i2ss3

study, therefore, age differences in drawing styles reflect the developmental changes in fine-motor skills (constructing small strokes in appropriate places with appropriate pressure) and motor inhibition (drawing slowly to be careful) in addition to developing cognitive abilities, including spatial understanding for constructing each stroke in the appropriate place. The results of the partial correlation controlling the effect of age revealed a significant relationship between BGT score and drawing speed, i.e., children who drew more slowly could copy the figures more accurately. This result indicated that the development of motor inhibition or self-regulation is essential for improving the BGT score. The present results also demonstrated that investigating the drawing process in addition to finished drawings produces richer information about children's visual and perceptual coordination. It is worthwhile for both clinicians and researchers to give more attention to the dynamic data of drawing tests for better understanding of children's developmental stages.

Drawing skills, including fine-motor skills and motor inhibition, are also important in handwriting, especially for Japanese children, because hiragana (Japanese cursive syllabary) and kanji (Chinese characters) contain many small strokes and require fine motor skills to control writing speed and pressure at the beginning and end of a stroke and at the contact point. Moreover, Japanese characters value the "stroke order," and elementary school teachers in Japan are earnest about teaching the correct order of writing. Computerized analysis of drawing and writing process can be applied to literacy education and special support for children with dysgraphia or difficulties in writing. Furthermore, comparing the drawing and writing process via Elian among different cultural backgrounds might provide new findings. For example, approximately70% of our participants in all age groups produced clockwise movements in drawing a circle, contrary to the finding in Western countries (Vinter & Meulenbroek, 1993). This discrepancy could be investigated regarding the differences in the two styles of handwriting (alphabet/hiragana). Alphabets contain letters that must be written counter-clockwise (e.g., o/e) in contrast with hiragana (e.g., め/の). Cross-cultural studies in drawing styles are expected in further research.

Sex differences were found in total length and average pressure, I.e., girls drew smaller figures and copied with stronger pressure than boys. As mentioned above, older participants drew smaller figures with stronger pressure. That is, the sex differences indicate that girls outgrew boys in drawing skills. This finding coincides with previous studies that demonstrated that girls are more advanced than boys in fine-motor development (Haywood & Getchell, 2009).

This study, conducted in Japan, revealed that the BGT total score increased with age. This finding was consistent with previous studies on the BGT (Bolen, 2003; Fernández & Tuset, 2007; Özer, 2011; Rajabi, 2009) in non-Asian countries. The results identified no differences in the

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number of strokes and duration among the three age groups. This outcome represents the reliability of this experiment, i.e., most of the participants followed the BGT procedure and drew all nine figures in a quantitatively stable manner. Although the older children copied the figures more slowly, they drew shorter lines, thus balancing the duration time.

The study revealed the performance of copying the BGT figures related to the drawing process and also demonstrated that the drawing tests provided more valuable information by analyzing *how* the participants drew in addition to *what* they drew, and that the digital pen (with Elian software) was technically feasible for objective analyses of the preschoolers' drawing activities. As our new method saves both time and expense for the clinical psychologists as well as researchers without specific training or knowledge about computers, it has unlimited potential for clinical application. It can be applied to not only BGT, but also Draw-A-Manand Rey Complex Figure, a trail-making test, a maze test, drawing of the family, and the House-Tree-Person test, etc. (Wallon et al, 2000). Analyzing drawing process also enables researchers to detect pathological signs, including obsessive-compulsive behavior (compulsive, repeating lines), impulsivity, Alzheimer's and Parkinson's diseases, writer's cramp, or depression. For further study, additional quantative investigation on typically and a typically developing children as well as cross-cultural study are required.

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