Bulletin of Fukuoka University of Education, Vol. 66, Part Ⅳ, 91–105 (2017)

# One factor contributing to difficulties in visual perception and visual-motor/constructional performance in children with cerebral palsy: Characteristics in hierarchical processing of global-local shapes (hierarchical compound stimuli)

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(Accepted September 30, 2016)

**Abstract**

This study examined a factor contributing to difficulties in visual perception and visual-motor/constructional performance in children with cerebral palsy (CP) based on characteristics of their hierarchical processing of global-local shapes (hierarchical compound stimuli) under conditions that encourage global preference. The participants were 19 children with CP (aged 7 years and 5 months to 18 years and 9 months). Under global preferential GS conditions (local: 0.6 degrees, global: 5 degrees), no significant difference was found between the number of shapes perceived at global and local levels based on drawings and card selection. In contrast, under relatively local preferential LL conditions (local: 5 degrees, global: 41.7 degrees), this number was significantly lower at the global level. It was found that the sensitivity to local components of stimuli in hierarchical processing was dependent on the size (visual angle) of the stimuli. As the global-local shapes showed significantly lower visual-motor/constructional performance than drawing scores for simple shapes, it can be concluded that this task requires a higher level of constructional ability. This suggested that difficulties in visual perception and visual-motor/constructional performance share problems in hierarchical processing of parts versus wholes as a common cause.

**Keywords**: Cerebral palsy  Global-local figure  Hierarchical compound stimuli  Visual perception  Visual-motor/constructional performance

## 1. Introduction

Children with cerebral palsy (CP) not only suffer postural and motor abnormalities, but also often exhibit a range of other problems, among which visual difficulties[1] have long been reported (e.g., Abercrombie, Gardiner, Hansen, Jonckheere, Lindon, Solomon, & Tyson, 1964). In Japan, the number of low-birth-weight infants has increased, reaching 9.6% of all infants born in 2011 (OECD, 2013), and a consequent rise in the number of children with spastic CP resulting from periventricular leukomalacia has been observed. In such children with CP, it is easy for periventricular abnormalities to damage the visual tract and cause visual information processing impediments (Koeda & Takeshita, 1992). Therefore, visual difficulties in children with CP have, in recent years, garnered renewed attention (e.g., Fedrizzi, Inverno, Bruzzone, Botteon, Saletti, & Farinotti, 1996; Ortibus, Lagae, Castees, Demaerel, & Stiers, 2009), making this both a new and an old problem. However, difficulties in children with CP have mainly been reported as low performance in various visual tasks, included in tests such as the Frostig Developmental Test of Visual Perception. Accordingly, it is essential that the factors contributing to these difficulties be investigated, as generally a majority of learning activities are based on vision.

Visual behavior in learning activities can be largely broken down into 'visual perception (or cognition)' → 'visual-motor (coordination)/constructional performance[2]': for example seeing notes on a board, followed by copying them into one's notebook. Children with CP are more often described as having problems with visual-motor/constructional performance than with visual perception. For example, Bortner & Birch (1962) stated that, given that children with spastic CP still discriminated between options in 77% of their mistakes in the block-design subtest of the Wechsler Intelligence Scale for Children (WISC), it cannot be said that those who fail the block-design subtests necessarily have problems with perception. On the other hand, problems with perception were indicated for the remaining 23% of mistakes. Menken, Cermak, & Fisher (1987) also reported that children with CP scored significantly lower perceptual quotients on the motor-free Test of Visual-Perceptual Skills (TVPS) than normal children. In addition, Narukawa (1978) reported that perception in children with CP using tachistoscopic vision was poor for line drawings, even for familiar daily objects and things. Furthermore, impairments in figure-ground perception have been pointed out in children with CP (e.g., Abercrombie et al., 1964; Barca, Cappelli, Di Giulio, Staccioli, & Castelli, 2010; Cobrinik, 1959; Dolphin & Cruickshank, 1951; Ghent, 1956; Nakamura, 1992; Nakatsukasa, Ogawa, & Fujita, 1971; Narukawa, 1978; Ortibus, De Cock, & Lagae, 2011)[3]. Given the above, there is an evident need to investigate the factors contributing to these perceptual level impediments in children with CP.

Kawasaki, Ohira, & Ichiki (2013), and Ohira, Ichiki, & Mizuta (2013), based on well-recognized clinical examples of difficulties, hypothesized that the heart of those difficulties is the ease in responding to parts combined with the difficulty in grasping the whole (hereafter, sensitivity to local components of stimuli). For instance, skipping ahead when reading textbooks is often regarded as an oculomotor problem, and results in poor balance between the size and position of letters as a constructional performance problem; however, these problems can also be considered a focus on the parts and inability to grasp the whole. Difficulty in constructing the figure as separate from the ground can be viewed in a similar way[4]. This is consistent with superior sequential processing and inferior simultaneous processing within the cognitive processing of children with spastic CP (Shimizu, 1999).

Hierarchical compound stimuli have been used to investigate global and local[5] level (hierarchical) processing. Navon (1977) found that when perceiving large letters (global letters) constructed from small-sized letters (local letters), processing is shouldered by two systems — perceptual processing of the global level (i.e., whole) and perceptual processing of the local level (i.e., parts), — the former took temporal precedence to the latter. Regarding this point, people with Williams syndrome have been found to have a tendency to omit the global level and write only the local level letters, while individuals with Down syndrome display obverse symptoms (Bihrle, Bellugi, Delis, & Marks, 1989). That is, global and local level processing can be evaluated independently. Later, Rondan, Santos, Mancini, Livet, & Deruelle (2008) found that although individuals with Williams syndrome did show a tendency towards the local level in a drawing task, they did not show this tendency in a forced-choice perception task. This indicates that the visual perception level and the visual-motor/constructional performance level can also be evaluated independently. In other words, by manipulating stimulus conditions using hierarchical compound stimuli, one hypothesized cause of difficulty in visual perception of children with CP, i.e., problems of hierarchical processing of the global and local levels, can be systematically investigated while still distinguishing between visual perception and visual-motor/constructional performance levels.

Regarding the visual perception level, Kinchla & Wolf (1979) used the letters H and S to show that when the visual angle of global letters was 6-9 degrees or less, the global level was most easily identified, while above the degrees, conversely, the local level was more easily identified. Navon & Norman (1983) responded by claiming that the local level was only processed preferentially because the shape of the global letters used in this investigation had the local letters positioned in the center: that is, the global letters included local letters positioned with a low degree of offset from the center (eccentricity). In other words, in the case of global letters/shapes like C or circular letters, where the local letters/shapes are not positioned within the center of the global letters/shapes, and clearly comprise the outer edge of the global letters (with a fixed degree of local letter/shape positioning eccentricity), the global level is processed preferentially, even when the size exceeds the visual angle of 6-9 degrees. Upon considering the above, Kawasaki et al. (2013) and Ohira et al. (2013) used circular, triangular, and square shapes, including basic line-drawing elements (curves, obliques, horizontal, and vertical lines), while satisfying the global-preferential conditions that the visual angle of the global level stimuli was 5 degrees or less and the positioning eccentricity of each local-level stimulus was relatively uniform. Using this design, the researchers investigated whether children with spastic CP reacted to global preferential conditions by giving preference to the local, whether or not they exhibited specific sensitivity to local components of stimuli. Although Ohira et al. (2013) reported a case showing specific sensitivity to local components of stimuli, Kawasaki et al. (2013) did not find any such sensitivity under global preferential conditions in the four cases they studied.

The present study investigated one factor contributing to visual difficulties, chiefly at the visual perception level, in children with CP, along with performance at the visual-motor/constructional performance level, based on characteristics of hierarchical processing of compound stimuli. Specifically, in terms of visual perception, the study revealed whether sensitivity to local components of stimuli can be observed under conditions of relative local preference, that is, where a response of global preference would normally be expected (Navon & Norman, 1983), but where the visual angle is 6-9 degrees or more. In other words, the study sought to determine whether or not condition-dependent sensitivity to local components of stimuli can be found.

## 2. Method

### 2.1 Participants

The participants in the study were students of a school for special needs education (for the physically handicapped) who attended because of their CP. A teacher of Jiritsu Katsudo (a subject designed to alleviate difficulties in aspects of daily life and learning resulting from students' impairments) assisted by selecting students with spastic CP who would be able to comply with the experimental procedure, based on the research contents. Consent for participation in the research was obtained from guardians after informing them of the purpose of the study and the ethical procedures involved.

Of the 21 students selected by the teacher, two were excluded for having difficulties completing the tasks for reasons of excessive psychological stress, leaving a total of 19 participants (see Table 1). These participants ranged from year two elementary school to year three upper secondary school students (ages 7 years and 5 months to 18 years and 9 months). Of these, 17 had been low birth weight babies or had exhibited periventricular leukomalacia. At schools for special needs education, students are able to study one of four types of curriculum according to their conditions. The participants in this study included 12 individuals who were studying a curriculum that corresponded to the regular school curriculum (commonly called regular school equivalent curriculum), one who was studying subjects similar to the above but at a lower year level (commonly called lower year alternative curriculum), and six students who were studying an alternative curriculum prepared for schools for special needs education of those with intellectual disabilities (commonly called

Table 1 Participant profiles

| Participant | Gender | Age | Curri-culum | Motor performance GMFCS-E&R | MACS |
|---|---|---|---|---|---|
| A | f | 7y.5m. | B | I | II |
| B | f | 9y.0m. | A | IV | I |
| C | m | 9y.3m. | B | III | III |
| D | f | 10y.2m. | B | III | II |
| E | m | 12y.9m. | B | III | II |
| F | m | 14y.5m. | A | IV | II |
| G | f | 15y.11m. | A | IV | III |
| H | f | 16y.0m. | A | IV | II |
| I | f | 16y.2m. | B | IV | IV |
| J | f | 16y.2m. | A | II | I |
| K | m | 16y.4m. | A | IV | II |
| L | m | 16y.10m. | A | III | II |
| M | f | 17y.4m. | B | IV | II |
| N | m | 17y.9m. | A | III | II |
| O | f | 17y.9m. | A | IV | III |
| P | f | 17y.9m. | A | II | II |
| Q | f | 17y.9m. | A | IV | II |
| R | m | 18y.3m. | A | IV | III |
| S | f | 18y.9m. | A' | IV | III |

Departments: The table is divided into 3 sections, with the top section being those in the elementary department, the middle level being those in lower secondary, and the bottom level being those in upper secondary.

Curriculums: A = regular school equivalent curriculum, A' = lower year alternative curriculum, B = intellectual disability alternative curriculum

intellectual disability alternative curriculum). However, the curriculum studied by each student was not determined by intelligence tests, but through the actual process of conducting lessons (i.e., the curriculum in which the student was capable of learning). In addition, the gross motor skills and upper limb functions were evaluated by the homeroom teacher of each participant using the Gross Motor Function Classification System Expanded and Revised (GMFCS-E&R) and the Manual Ability Classification System (MACS), respectively. The participants' GMFCS-E&R levels were between I and IV, as were their MACS levels.

The relationship between shape size and hierarchy within the stimulus can affect visual perception performance. To examine this, the difference between stimulus conditions within each participant was investigated. Using this methodology, factors other than the relationship between shape size and hierarchy within the stimulus thought to directly influence task performance, that is, aspects of visual function, upper limb function, and intellectual functions (specifically task understanding) could be directly grasped based on the results of performance in a task using simple shapes of the same size as the global-local shapes.

## 2.2 Stimuli

The stimuli used were circles, triangles, and squares. Participants viewed the shapes displayed on a monitor. The participants were given a global-local shape (hierarchical compound stimuli) task (hereafter, the hierarchical compound shape task) and a simple shape task.

*The hierarchical compound shape task* — The local shapes were circles, triangles, or squares, and each local shape was arranged in the shape of a circle, triangle, or square (the global shape). After eliminating shapes where the local and global shapes were the same, a total of six types of shapes were used as stimuli (see Fig. 1). These stimuli had the following two conditions. First, the size of the whole shape, i.e., the global shape, was small, giving preference to the global (Global advantage – Small size, hereafter, GS conditions); second, the size of the global shape was large, giving comparatively greater preference to the local (Local advantage – Large size, hereafter LL conditions). Specifically, under GS conditions, the visual angle of the global shape was set at 5 degrees or lower based on previous studies, giving preference to the global. Similarly, the visual angle of the local shape, giving preference to the global, was set at 0.6 degrees or lower (Martin, 1979). The visual angle is determined by the visual distance and its actual size. Thus, so that the visual distance would be between 40cm and 50cm, the standard global level size under GS conditions was set at 4cm on the monitor, making the standard local level size 0.48cm. The equilateral triangles and squares inscribed in a 0.48cm circle acted as the local-shape triangles and squares, respectively. The circle midway between the inscribed and circumscribed circles of each shape was treated as their respective intermediate circle; the circle midway between the intermediate circle of the triangle and the intermediate circle of the square acted as the local-shape circle. Each shape at the global level — a circle, a triangle, and a square — was created based on the same standard global-level-size (4cm) circle, using the same method as for the local shapes. The local shapes were inscribed as 12 circles, triangles, or squares, equally spaced to form the global shape, creating the global-local shape. However, in the case of triangular or square local shapes being used to form a circular global shape, inscribing the local shapes distorted the global shape. To avoid this, the local shapes located along a smaller concentric circle, the outline of which passed through the centers of each local shape, and then they were inscribed in the circular global shape.

The visual distance was fixed at 45.8cm, such that the visual angle of the global shapes was 5 degrees or less and the visual angle of the local shapes was no more than 0.6 degrees.

Under LL conditions, the local shape size was set at the same as the global shape size under GS conditions. Thus, the global shape size was reverse-calculated based on the local-global ratio of the visual angle, and set at 41.7 degrees. Shapes were constructed based on this size using the same method as for the shapes under GS conditions.

*The simple shape task* — The same circles, triangles, and squares used in the hierarchical compound shape task were used as stimuli in the simple shape task. However, different from the hierarchical compound shape task, simple shapes of regular circles etc. with no hierarchical layers were used. Three size patterns were set corresponding to the size of the global and local shapes under the GS and LL conditions (the local shape size under GS conditions; the global shape size under GS conditions/the local shape size under LL conditions; and the global shape size under LL conditions). Circles, triangles, and squares of each size were prepared for a total of nine types of stimuli used.

### 2.3 Stimuli Presentation and Procedure

Participants sat on wheelchairs or regular chairs facing a desk, and viewed shapes displayed on the monitor. In order to keep the visual distance constant as much as possible, a 45.8cm scale was created and the distance between each participant's eyes and the monitor was measured directly before displaying each shape.

After confirming the visual distance, a visual pre-stimulus cue (an asterisk) and an audio pre-stimulus cue (a chime sound lasting for about

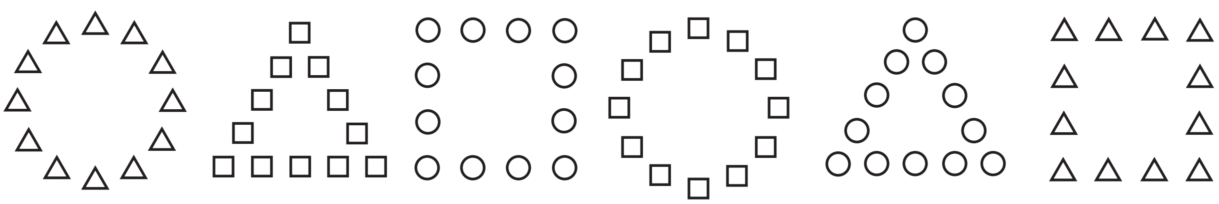

Fig. 1 Global-local shapes used in the hierarchical compound shape task (hierarchical compound stimuli)

1 second) were presented simultaneously. The visual pre-stimulus cue was shown for a continuous period of 3 seconds. Then, one shape was shown and removed after 1 second. The stimulus duration was 1 second. It can be considered sufficient for perception in both the simple shape task and the hierarchical compound shape task (Narukawa, 1978), while being not necessarily sufficient time for scanning by ocular movement.

After stimulus presentation ended, participants reproduced what they had seen. The reproduction method was to have participants reproduce exactly what they had seen by drawing, based on a previous study (Bihrle et al., 1989). Even within the actual lessons students attend for their school subjects, students' vision is often inferred from the state of completion of their notes when they copy content from the blackboard into their notebooks. However, children may have difficulty in drawing due to issues in both visual perception and constructional performance including visual-motor performance. In the light of this possibility and based on the finding of Rondan et al. (2008), a check was added in the form of having students select the object they had seen from a number of cards. Accordingly, visual perception was evaluated using both the results of the drawing and the card selection, and constructional performance using the drawing results after taking into account the card selection results. Card selection was done using a multiple choice method, where participants selected the card showing the same shape they had seen from either a selection of three cards (for the simple shape task) or six cards (for the hierarchical compound shape task). In the simple shape task, to avoid participants not selecting the correct card because the size of the shape shown differed from that they had seen, the shape shown in the three cards was of the same size as the stimulus given. This was the same in the hierarchical compound shape task. However, as the shapes under LL conditions were too big, all six cards could not be shown at once, and thus in the hierarchical compound shape task three cards were shown at a time, making sure that the first three cards shown did not include the correct answer.

The tasks were carried out in the following order: 1) the simple shape task, 2) the hierarchical compound shape task under GS conditions, and 3) the hierarchical compound shape task under LL conditions.

### 2.4 Analysis

Results were included in the analysis when it was confirmed that there were no problems in visual function, upper limb function, or task understanding in the simple shape task.

*Drawing* — A standard was formulated to express the degree of constructional performance, based on a points system. As an absolute standard, a broad point scale was created for the "distinguishability" of the shape, and a relative standard was formulated by creating subdivisions based on the differences in performance between each of the drawings made.

- ✓ 0 points: nothing drawn, the drawing has no shape (a scribble, the global-level shape is clearly only a row of local-level shapes, etc.);
- ✓ 2 points: not clear (the participant is attempting to construct a shape but it is unclear what it is);
- ✓ 4 points: the viewer can basically make out what was drawn (viewer can tell whether the drawing is a circle, triangle, or square, but it is not definitively distinguishable);
- ✓ 6 points: the overall shape is clear but is distorted, the shape is partially abnormal and inadequate; quite a lot of distortion makes it unclear (the shape is sufficiently clear, but straight and/or curved lines are very wobbly, corners have clearly not been joined, some corners look like curved lines, i.e., the drawing does not sufficiently fulfill the conditions of the original shape; if viewed on its own it is difficult to define, but upon comparison the drawings are distinguishable);
- ✓ 8 points: the overall shape is clear but is distorted, the shape is partially abnormal and inadequate; clear with little distortion (straight and/or curved lines show little distortion, but there are

small abnormalities e.g. the overall shape is slanted, asymmetrical, and corner and circle joins are a little off); and

- ✓ 10 points: the shaped is fully expressed.

Six points and above was considered distinguishable. In the hierarchical compound shape task, points were given for both the global and local level. The "number" of shapes at the local level was included in the score for the global-level shape. For the local-level shapes, where there were multiple local shapes, the score was taken to be the midpoint between the highest and lowest score. Where the global shape was drawn as a simple shape separate from the local shapes (e.g., a global-level circle shape is drawn as a simple shape and several local shapes are drawn along part of it), the drawing could only receive 0 points because it was not comprised of local shapes. This was true even if the drawing would receive 6 points or more as a simple shape for being the same shape as that given in the stimulus. Points were given where the wrong card was selected but the drawing was evaluated as having the right shape: it would receive 6 points or more for being the same shape as that of the stimulus. On the other hand, however, the response was not scored and removed from analysis when it was considered that the participant had clearly misunderstood the stimulus: e.g., the drawing and the card selected afterwards were the same but were different to the shape shown as the stimulus.

In terms of the reliability of the points system, the Spearman's rank correlation coefficients of the points awarded to drawings by two persons not otherwise related to the study were .74 ($p$<.001) for the simple shape task and .88 ($p$<.001) for the global-level shapes of the hierarchical compound shape task.

*Visual perception level task performance* — Within the hierarchical compound shape task, in addition to cases where the shape drawn was indistinguishable while the card selected was correct, there were also cases where the correct shape was drawn while no card was selected (the participant claimed none of the cards matched) or the wrong card was selected. Accordingly, participants were considered to have perceived the shape where they had 6 points or more for the drawing and/or had selected the correct card. In addition, participants were considered to have visually perceived the shape where they had been given a score of 0 because they had drawn a simple shape at the global level, but this was the correct shape. At the local level, this was judged based on a participant's highest score.

*Statistical tests* — The Wilcoxon signed rank test was applied to compare the two groups. An exact $p$-value was obtained using the exact test (two-sided test).

## 3. Results

### 3.1 Visual function, Upper Limb Function, and Task Understanding

According to the results of the simple shape task, it was determined that each of the participants had sufficient visual function, upper limb function, and task understanding to complete the hierarchical compound shape task.

Although there were seven participants (B–E, I, K, R) who drew one or more drawings in the simple shape task that did not earn 6 points (i.e., drawings that were indistinguishable), each participant's median score was 6 points or more. Furthermore, in most cases, shapes were not only distinguishable, but participants adequately reproduced the difference in size in their drawings.

The card selection results also showed that only two of the 19 participants, selected the wrong card, in just one case each: all other selections were correct. A closer look at the wrong answers revealed that one (participant M) selected a circle instead of a square at a visual angle of 0.6 degrees. The other (participant D) claimed that none of the cards were correct when the correct answer was a circle at visual angle of 0.6 degrees, and drew an asterisk-type symbol. When asked to point to the shape that was shown after the asterisk, the participant then selected the correct card.

### 3.2 Task Performance at the Visual Perception Level: Drawing and Card Selection Tasks

In the hierarchical compound shape task, three participants' visual perception level accuracy could be determined from all of the 24 shapes:

that is, six shapes (3 types × 2 times) each at the global and local levels (2 levels) of both GS and LL conditions (2 conditions), in both drawing and card selection. Of the remaining 16 participants, there were cases where it could not be determined from their drawing of the shape, but could be determined from the card selected. The median across all participants for the number of the corresponding shapes was 6 (range: 4 [25%] — 8 [75%]). Within this, eight participants also had cases where visual perception level ability could be determined by the drawing but not by the card selected. The median across all participants for the number of the corresponding shapes was 2.5 (range: 2 [25%] – 4 [75%]).

The number of perceived shapes, under GS and LL conditions, at the global and local level, and based on the results of the drawing and card selection, are given in Fig. 2. Under GS conditions, no significant difference was found in the number of perceived shapes at each level ($p$=.75). In contrast, a significant difference was found between each level under LL conditions ($p$=.031).

Twelve participants perceived all of the shapes under both GS and LL conditions. Of the remaining seven participants, one participant was unable to perceive one shape at each level under GS conditions only, but successfully perceived all shapes at the LL condition (see G in Fig. 2). A further two participants (A and M) were able to perceive a greater number of shapes at the global level than at the local level, and two more participants (C and D) were able to perceive a greater number of shapes at the local level than at the global level, under GS conditions. In the former group, both participants conversely were able to perceive all of the shapes at the local level, but not all of the shapes at the global level, under LL conditions. In the latter group, the number of shapes perceived at the global level under LL conditions was even smaller. The remaining two participants (B and I) were able to perceive all of the shapes under GS conditions, but not all of the shapes at the global level under LL conditions.

### 3.3 Task Performance at the Visual-motor/Constructional Performance Level: Drawing Task

Table 2 compares the results between the drawing scores for global-level and local-level shapes under GS and LL conditions in the hierarchical compound shape task, and

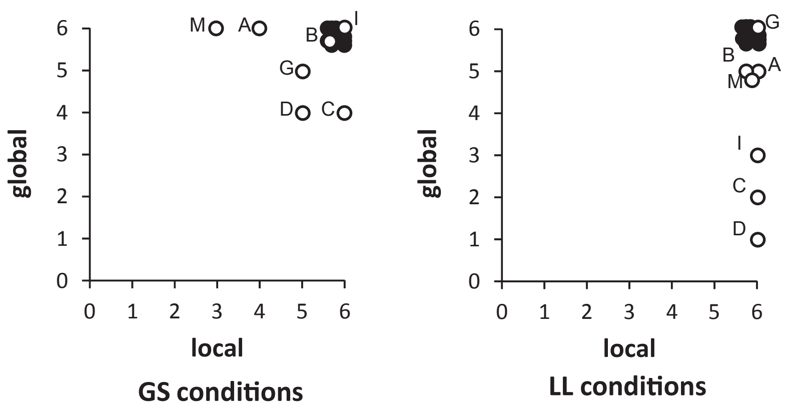


Fig. 2 Number of perceived shapes as determined based on the drawing and card selection tasks

Shown by global and local levels for each of GS and LL conditions. Where the plotted points overlap, they are displayed slightly off-center. Each plotted point represents one participant, with ● representing participants who were able to perceive all shapes under both sets of conditions. All other participants are represented by ○. The letters attached to each ○ are the same letters used to identify each of the participants in Table 1.

Table 2 Drawing scores at each level of the hierarchical compound shape task and corresponding scores of the simple shape task, and comparison

| Task | Conditions | Level | Angle | Shape | n | Me | (25% - 75%) | p-value | |
|---|---|---|---|---|---|---|---|---|---|
| Hierarch. comp. shape | GS | local | 0.6 | ○ | 18 | 8 | ( 7 - 9.5 ) | $p$=.721 | n.s. |
| Simple shape | — | — | 0.6 | ○ | 18 | 8 | ( 8 - 10 ) | | |
| Hierarch. comp. shape | GS | local | 0.6 | △ | 19 | 9 | ( 7.5 - 10 ) | $p$=.573 | n.s. |
| Simple shape | — | — | 0.6 | △ | 19 | 8 | ( 8 - 10 ) | | |
| Hierarch. comp. shape | GS | local | 0.6 | □ | 18 | 8 | ( 7.25 - 9 ) | $p$=.231 | n.s. |
| Simple shape | — | — | 0.6 | □ | 18 | 9 | ( 8 - 10 ) | | |
| Hierarch. comp. shape | GS | global | 5 | ○ | 19 | 4 | ( 4 - 5 ) | $p$<.001 | ** |
| Simple shape | — | — | 5 | ○ | 19 | 6 | ( 6 - 8 ) | | |
| Hierarch. comp. shape | GS | global | 5 | △ | 19 | 6 | ( 4 - 7 ) | $p$<.001 | ** |
| Simple shape | — | — | 5 | △ | 19 | 8 | ( 6 - 8 ) | | |
| Hierarch. comp. shape | GS | global | 5 | □ | 19 | 6 | ( 5 - 7 ) | $p$<.001 | ** |
| Simple shape | — | — | 5 | □ | 19 | 8 | ( 6 - 8 ) | | |
| Hierarch. comp. shape | LL | local | 5 | ○ | 19 | 8 | ( 6 - 9 ) | $p$=.211 | n.s. |
| Simple shape | — | — | 5 | ○ | 19 | 6 | ( 6 - 8 ) | | |
| Hierarch. comp. shape | LL | local | 5 | △ | 19 | 8 | ( 7 - 9 ) | $p$=.193 | n.s. |
| Simple shape | — | — | 5 | △ | 19 | 8 | ( 6 - 8 ) | | |
| Hierarch. comp. shape | LL | local | 5 | □ | 19 | 8 | ( 7 - 8 ) | $p$=.672 | n.s. |
| Simple shape | — | — | 5 | □ | 19 | 8 | ( 6 - 8 ) | | |
| Hierarch. comp. shape | LL | global | 41.7 | ○ | 18 | 4 | ( 4 - 5 ) | $p$<.001 | ** |
| Simple shape | — | — | 41.7 | ○ | 18 | 6 | ( 6 - 6 ) | | |
| Hierarch. comp. shape | LL | global | 41.7 | △ | 17 | 5 | ( 4 - 6 ) | $p$=.002 | ** |
| Simple shape | — | — | 41.7 | △ | 17 | 6 | ( 6 - 8 ) | | |
| Hierarch. comp. shape | LL | global | 41.7 | □ | 18 | 6.5 | ( 6 - 8 ) | $p$=.293 | n.s. |
| Simple shape | — | — | 41.7 | □ | 18 | 6 | ( 6 - 8 ) | | |

** $p$<.01, n.s.: not significant, the exact Wilcoxon rank-sum test

the drawing scores for the shapes at the corresponding visual angles in the simple shape task. In the hierarchical compound shape task, the median score was used as the score for each shape since there were two of each of the shapes (circle, etc.) at the global and local levels, respectively. Where one of the scores was excluded from analysis because it could not be determined to have been perceived based on the drawing and card selection, the remaining score was adopted.

No difference was found between the drawing scores for the local shapes in the hierarchical compound shape task and the drawing scores for the corresponding visual angles in the simple shape task under either GS or LL conditions. In contrast, a significant difference was found between the drawing scores for the global shapes in the hierarchical compound shape task, and the drawing scores for the corresponding visual angles in the simple shape task, with the exception of the square under LL conditions.

## 4. Discussion

### 4.1 Visual Perception

From the simple shape task, it was grasped that each participant had sufficient visual function, upper limb function, and task understanding to complete the task.

In the hierarchical compound shape task, just as in the simple shape task, there were many shapes that could be determined to have been perceived in both the drawing and card selection. However, there were also shapes that could not be determined to have been perceived in the drawing, but for which the correct card was selected. In actual classroom teaching, judgment is often made based on drawn or written work, with cases like the above tending to be overlooked, and this is the same with previous studies targeting those with Williams syndrome, as stated above. Meanwhile, there were also shapes where the wrong card was selected despite the drawing clearly showing that the participant was able to perceive the shape. This is thought to be an issue of memory retention caused by loss of concentration on the task(s) at hand. Although the simple shape task confirmed that participants did not have problems with memory function, this phenomenon is thought to be attributable to the fact that the volume of stimuli information participants were expected to retain was greater in the hierarchical compound shape task, and the length of time required for drawing was also longer. When guiding children, such factors need to be taken into consideration in evaluation.

We examined the number of perceived shapes. No significant difference was found between the global and local levels under the same GS conditions for stimuli used by Kawasaki et al. (2013). This result is consistent with Kawasaki et al.'s findings. In contrast, under the new LL conditions set in this study, a significant difference was found between the global and local levels. These results indicate that, despite the fact that global preference is expected for both the GS and LL conditions alike (Navon & Norman, 1983), while no sensitivity to local components of stimuli was observed for the GS conditions, it was observed for the LL conditions, in which the (larger) size of the stimuli was expected to have conferred an advantage to local perception (relative to the tendency under GS conditions): in other words, conditional sensitivity to local components of stimuli was observed.

Meanwhile, 12 out of 19 participants were able to perceive all of the shapes in the hierarchical compound shape task. However, most of these were upper secondary school level students. This indicates the possibility of an interaction where younger children are more susceptible to the effects of the stimuli conditions. Kozeis, Anogeianaki, Mitova, Anogianakis, Mitov, & Klisarova (2007) reported a positive correlation between perceptual age (PA) and chronological age (CA) in the Motor-Free Visual Perception Test (MVPT-R). This implies that PA improves and develops with age. Furthermore, Ohira et al. (2013) found such improvements when conducting the Frostig Visual-Perceptual Training Program with children with CP who showed specific sensitivity to local components of stimuli. This suggests the possibility that sensitivity to local components of stimuli also improves with age and development. Meanwhile, of the 12 participants who were able to perceive all of the shapes, 11 were studying the regular school equivalent curriculum, and conversely of the seven participants who made mistakes, five were studying the intellectual disability alternative curriculum. At first glance, it appears that the task performance results in this study bear some relationship with intellectual function. This could be related to two things. The first is that the curriculum decision for the participants was a result not of an intelligence test (although this test would be in part affected by visual and motor difficulties), but determined through actual classroom performance. In other words, the curriculum studied by the participants does not necessarily reflect their intellectual function, and may in fact reflect learning difficulties resulting from visual difficulties rather than intellectual disability. The second is that information on participants' intellectual function, like the presence or absence of intellectual disability, reflects the extent of cerebral function. Because of this, the extent of intellectual function may indirectly reflect the extent of visual hierarchical processing function. In other words, there may be interaction between intellectual function and hierarchical processing, both of which act as factors underlying their visual difficulties. However, the fact that some participants studying the regular school equivalent curriculum also made mistakes suggests that there are cases of selective dysfunction of the visual processing system, separate from that of intellectual function as overall cerebral function. Kozeis et al. (2007) found visual perception disability even in children with CP who had an IQ of 70 and above. Menken et al. (1987) also found that CP children with normal IQ showed significantly lower perceptual quotient than did normal children. There is therefore a need for further investigation taking into account not only the stimuli conditions (environmental factors)—i.e., for what stimulus attributes are difficulties observed—but also individual factors such as age and intellectual function.

Next, let us examine the aspects of the conditions and levels that led to differences in the number of perceived shapes, at the individual level. As stated above, one can surmise from many successful cases that the task used in the current study is easy. As such, it is interesting to note that errors could be made by about 40% of participants in such a task, consistent with Ego et al. (2015). Of the seven participants who made errors, one participant (participant G in Fig. 2) made a mistake in one shape each for the global and local levels under GS conditions. The error was a reversal of the global and local levels for the same stimuli in both the drawing and card selection. There could be various causes for this. One of these was identified by Kawasaki et al. (2013): that the participant does not retain memory of the shapes at each level as the perceived image, but rather they take the strategy of replacing the shapes with words, and level-specific information is lost. However, this warrants further investigation, since we do not know the mechanism for this reversal phenomenon. If we examine the remaining six participants, under GS conditions, there were two participants who gave preference to the global and two who gave preference to the local. The remaining two were able to perceive all of the shapes. One of the participants who gave preference to the global (participant M) also made a mistake in the simple shape task at a visual angle of 0.6 degrees. In addition, she numerous times drew simple shapes showing the global level only and missing the local level in drawings in the hierarchical compound shape task. Influences of visual acuity such as the crowding effect are suspected from these. These participants (A and M) were able to perceive all of the local-level shapes under LL conditions. This indicates the possibility that visual perception at the local level becomes more difficult when visual angles drop below a certain point. However, separate from this, global level errors were seen under LL conditions despite the participant being able to perceive everything at the local level. This means that we can say that an overall local preference was found under these conditions. Meanwhile, the two participants who gave preference to the local (C and D) both showed even starker local preference under LL conditions. Of these, one (participant C) was described by the school homeroom teacher as showing autistic tendencies. Koldewyn, Jiang, Weigelt, & Kanwishe (2013) have experimentally shown that children with autism exhibit not a “global deficit” but a “local preference.” The results of participant C can be said to be consistent with such a clinical manifestation as well. However, the other child (participant D) showed the same results, despite having not been described as particularly exhibiting such autistic symptoms. Therefore, participant D to some extent can be described as showing specific sensitivity to local components of stimuli, and this is expressed as markedly condition-dependent. The remaining two participants (B and I) were able to perceive all of the shapes under GS conditions at both levels, but made some errors at the global level under LL conditions. We can with confidence say that a condition-dependent local preference was observed again.

Condition-dependent sensitivity to local components of stimuli also appears to be consistent with the following clinical manifestations of children with CP. When children with CP try to view something, they are often seen drawing their eyes closer to it. This can be interpreted as them creating their own local preference conditions. In fact, this appears to be consistent with the fact that, sometimes, when students are unable to complete a visual task well (i.e., when they are creating their own local preference conditions), they become able to complete this task when instructed to move away from the task (the paper) and take a good look at it as a whole: they may not necessarily show the same difficulty under global preference conditions. On the other hand, 12—the majority—of the 19 participants in this study were able to perceive at both the global and local level, indicating that the task used was easy. However, this point warrants further investigation, since such cases may show local preference depending on the stimuli and their presentation conditions.

### 4.2 Visual-motor/Constructional Performance

The drawing of circles and other shapes in the simple shape task required shape construction by the participants. However, the nature of the hierarchical compound shape task could have required a higher level of construction. To resolve this, the results of drawings in both tasks were compared. No difference was found between the drawing scores for the simple shape task and the drawing scores for the same local shapes in the hierarchical compound shape task. In contrast, a significant difference was found between the drawing scores for the global-level shapes in the hierarchical compound shape task (excluding the square under LL conditions) and the drawing scores for the same shapes of the same size in the simple shape task. These results indicate that the hierarchical compound shape task requires a higher level of constructional performance, and is thus effective in evaluating constructional performance in children with CP. However, no significant difference was found for the global level square under LL conditions. Shapes under LL conditions were large, and some participants thus made their drawings larger, but the edge of the paper may have acted as a guide here. On the other hand, the fact that circles and triangles are constructed of curved and diagonal lines appears to have made these more difficult. Regarding diagonal lines in particular, this is consistent with findings of prior studies (Nakamura, 1992; Shochi, 1971).

Nakamura (1992) found that children who were able to accurately copy things onto paper had little problem with figure-ground perception, while those who could not showed a tendency towards figure-ground perception impairment, regardless of whether or not they were able to draw. He considered issues with ocular movement to be one factor that may explain the relationship between difficulties in figure-ground perception and in drawing. Perceiving figure-ground perception stimuli with complex stimuli arrangements in an instant is difficult, he argued, and requires appropriate scanning of the stimuli by the eyes; similarly, drawing is difficult without the appropriate ocular movement. However, the stimuli used by Nakamura were particularly complex, and it is doubtful whether the presentation time of only 2 seconds allowed for sufficient scanning, and not just for children with CP. Moreover, studies have shown that relieving time constraints (i.e., to allow ocular scanning) improved results to a level equivalent to that of normal children (Konno, 1976; Nakatsukasa et al., 1971; Narukawa, 1978), indicating that the results of Nakamura's study are difficult to explain with ocular movement. It seems more appropriate to assume that global level processing ability, which handles perception of the whole, is required to grasp shapes without ocular scanning. This is consistent with the notion that weakness in the ability to construct a whole from individual elements is at the root of figure-ground perception impairment (Cruickshank, Bice, & Wallen, 1957; Wedell, 1960). Thus, figure-ground perception impairment and drawing difficulty are thought to be caused not by the ocular movement issues suggested by Nakamura, but rather by a problem with the ability to grasp the whole. Of course, drawing difficulty can arise not only from constructional problems but from visual-motor problems as well; and problems in visual perception may not be detected by some conditions of certain tasks (a notion supported by the majority of participants who perceived all of the shapes in this study). Thus, it is likely that, as a result, many cases have been deemed to show difficulty in constructional performance (such as in drawing) despite having no problems with visual perception.

In conclusion, this study indicated that children with CP can exhibit problems not only at the level of output but also at the perception level of the input stage, due to problems with hierarchical processing of parts and wholes. However, this proved not to be a perceptual deficit per se, but rather condition-dependent perceptual dysfunction. Thus, future studies should first further investigate the effect of task conditions, including stimulus attributes, on visual perception.

## 5. Conclusion

The hierarchical compound shape task used in this study was relatively easy, and about 60% of children with CP were able to perceive all of the stimuli. However, even under those stimulus conditions, about 40% of participants were not able to perceive them and made mistakes. These findings suggest that children with CP, as has previously been identified, are a heterogeneous group, and that the task conditions that create visual difficulties differ from individual to individual. In the cases of mistakes, the influence of stimulus size (visual angle) was consistent among individuals: they were found to exhibit the characteristic of responding readily to parts—i.e., having difficulty grasping the whole—when the visual angle of the stimuli became larger. Children with CP have been previously noted to show the phenomenon of reaction to parts within mistaken reactions; however, our finding has shown that this tendency is not observed unconditionally, but rather in a stimulus condition-dependent manner. In addition, in the drawing task where participants reproduced the shape that they had perceived task performance was lower when greater hierarchical processing was required, including for participants that did not make any errors at the perceptual level. While children with CP have been identified in prior research to more readily show deficits at the visual-motor/constructional performance levels than at the perceptual level, these observations seem to be due to a higher burden placed on processing: i.e., to continue drawing while updating hierarchical processing of the parts and the whole in visual-motor/constructional performance. However, because the number of participants in this study cannot be considered large, it is necessary to increase the number of participants and confirm this going forward.

## Additional remarks

This work was supported by JSPS KAKENHI Grant Number 25381313.

## Notes

1 Prior studies have used many terms, including visual perception impairment and visual-motor impairment, with the former sometimes being used to include motor aspects (visual-motor), and thus the terms as well as the relationship between these terms and patient conditions are inconsistent. Here we refer to difficulties in all kinds of activities that use vision.

2 In this paper, "visual-motor coordination" will be used to refer to the coordination of vision and movement in particular, while the output that results from this coordination will be referred to as "visual-motor performance" (e.g., that which can be evaluated from tracing task). "Construction" will be used to refer to the cognitive capacity required for constructing, and the construction output as a result of visual-motor performance will be referred to as "constructional performance".

3 Figure-ground perception impairment and its essential nature remain unclear. Stimuli used are inconsistent and include Rubin's (1969) reversible figures, figures made up of colored parts and white background like those used in the block design subtest of the WISC, overlapping figures (constructed out of shapes that overlap and whose contours intersect), and embedded figures (constructed out of shapes that partly share contours). For this reason, the abilities variously investigated as "visual perception ability" may be different things.

4 Cruickshank, Bice, & Wallen (1957) suggested that the ability to organize individual stimuli into a whole was a crucial factor causing perceptual impairment. Wedell (1960) investigated this using a test thought to measure this organizational ability, and the result supported Cruickshank et al. It indicated that this ability to "organize" individual stimuli into a whole formed the basis for distinguishing between ground and figure. However, the majority of studies since then have treated this as a "figure-ground perception" ability impairment. Some of these studies are based on the above hypothesis, but these only report a phenomenon of reaction to parts within

mistaken reactions, and ultimately are doing nothing more than interpreting difficulties found in figure-ground perception tasks based on the above hypothesis.

5 Some take the view of distinguishing between problems of whole versus parts and global versus local, but our study treated these as equivalent, without distinction.

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