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Correlation between musical responsiveness and developmental age among early age children as assessed by the Non-Verbal Measurement of the Musical Responsiveness of Children

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

Background: The currently-available standardized music tests are not suitable for administration to young children and children with special needs because they are complicated and require verbal instructions and verbal responses. A test that was named the Non-Verbal Measurement of the Musical Responsiveness of Children, was developed to assess the musical responsiveness of young children. This test does not depend on verbal instructions, and is composed of two parts, Rhythm and Melody.

Material/Methods: Ninety-two children [age, range, 6–69 months; 36.39±17.61 (mean ±standard deviation) months] who attended mainstream pre-schools were studied. Each child was tested to see whether the child correctly imitated 7 different patterns of rhythm and 6 different patterns of melody that were delivered by clapping of hands or the voice of the examiner, respectively. The examiner rated whether the child could imitate each pattern and the total score was the sum of successfully reproduced patterns. Two independent observers viewed videotapes of the testing sessions and assigned scores in a similar manner. The inter-rater reliability among the three raters was assessed.

Results: The total score in Melody ($R=0.63$, $p<0.001$) and the total score in Rhythm ($R=0.81$, $p<0.001$) were each correlated with developmental age. The inter-rater reliability was good (Melody: Kendall's $W=0.78$, Rhythm: Kendall's $W=0.95$).

Conclusions: The degree of musical responsiveness of normal young children is correlated with general development. This measurement tool is valid and reliable for use in young children who lack sufficient verbal understanding to take standardized music tests. This test may also be administered to children with special needs.

key words: **musical responsiveness • non-verbal measurement • child • developmental age • correlation**

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BACKGROUND

General pediatric developmental tests are used to assess the general development of children and are administered at health care centers, clinics and pediatric sections of hospitals. These pediatric developmental tests are composed of items that assess the development of postural adjustment, gross and fine motor skills, social behaviors, lifestyle, and linguistic, adaptive, and cognitive abilities. None of these pediatric developmental tests, however, contains an item that assesses the musical responsiveness of children. Some developmental scales that are used to assess the development of children partly rely on information provided by their parents. For example, the Japanese Edition of the Denver Developmental Screening Test (JDDST) [1] was developed for children under 6 years of age, and consists of 104 tasks or items. Each item belongs to one of the following four categories: individual-society, fine movement-adaptation, language, and gross movement. A child is considered to be 'delayed' in an item if he or she cannot accomplish the behavioral task that 90% of children in the same age range can. Based on the number of items in which the child is 'delayed' in each category, a child is defined as belonging to one of the following four classes: 'abnormal', 'questionable', 'impossible', and 'normal'.

The scores on developmental scales in which the development of the child is assessed partly based on information provided by the child's parents tend to be unduly high, because parents tend to describe their child as being better than the child actually is. In addition, individual parents have not been trained in making assessments on such tests. Parents describe the state of their child with ordinary words. However, ordinary words may have slightly different meanings to different parents. Among professional raters who assess the development of children using the JDDST, the standard of classifying children into the four classes described above and the approach through which they comprehend children can also vary. This situation can sometimes result in an unduly high or unduly low score for individual children. With the JDDST and similar tests, the results of assessment for individual children vary among specialists according to their expertise.

The aim of this study was to develop a tool for assessing the musical responsiveness of children including very young children, which does not depend on verbal instructions. Various music tests have been developed to assess the musical ability, talent, capacity, aptitude and musicality of subjects [2–11]. These tests have been frequently used and are now regarded as standardized music tests [12,13]. Table 1 shows features of the standardized music tests that have been developed including the target subjects, time of administration of the test, and content. These music tests can generally be administered to individuals aged 8 years and older. Although Gordon's 'Advanced Measures of Music Audiation' (1989), for example, is now highly regarded as a reliable test, this test was developed for children in grade 4 and above. Although Gordon designed another music test, 'Audie' (1989), for children aged three to four years, this test requires the child to answer verbally. Music tests in which the subject must provide verbal answers, cannot be administered to children at the pre-verbal or non-verbal stage. In addition, the time of administration of these tests is too long for the attention span of young children. If these tests are administered to young children, the results of the tests may not accurately reflect their musical responsiveness.

To summarize, it is difficult to administer the existing music tests to young children between the ages of 0 month and 5 years for the following reasons: (1) the existing music tests were designed for older children; (2) the time of administration of the existing music tests is too long for the attention span of young children; (3) the content of these tests is too complicated for young children to understand; and (4) in the existing music tests, subjects must be able to understand verbal directions and to answer verbally; however, the present study focuses on the musical responsiveness of early age children including children at the pre-verbal or nonverbal stage.

An ideal tool for assessing the musical responsiveness of early age children should have the following features:

1. It can be administered to children younger than the subjects of musical developmental tests that have been developed to date;
2. The examination can be completed within a time period during which the child can maintain his/her concentration on the examination;
3. It is not complex and can be understood by young children;
4. The ideal tool can be administered to children under 1 year of age, and the test should be understandable without a spoken or written explanation;
5. The subjects do not need to respond with verbal expression;
6. Assessment of the general development of the child does not depend on indirect information, such as information from the parents.
7. Reproducible results can be obtained regardless of the level of expertise and the standard of judgment of the raters who make the assessment.

MATERIAL AND METHODS

Participants

The innate musical responsiveness of 94 normal children [age, 36.35±17.65 (mean ±SD) months] who attended three mainstream pre-schools was tested. The following children were excluded as these conditions may affect the results: (1) children who were found to be at risk for pervasive developmental disorder based on the standard pediatric developmental scale named "The New Edition of the Kyoto Scale of Psychological Development"; (2) children who were taking or have taken music lessons; (3) children whose parents' native language was not Japanese; and (4) children who had hearing problems as demonstrated in the auditory brainstem response (ABR) test that was administered at their annual health check-up examination.

Upon re-checking the characteristics of the children with the exclusion criteria, two participants were omitted from the study. Therefore, 92 subjects were included in the analysis. Among the 92 children, there were 50 boys and 42 girls. The children were aged between 6 months and 69 months [36.39±17.61 (mean ±SD) months]. Detailed oral explanations of the study were provided to the directors and teach-

Table 1. Major standardized music tests.

Name of the test	Year*	Target Subjects	Time of administration	Musical features that are assessed
Seashore measures for musical talent	1919	10yr~adults	60 min.	Pitch, Loudness, Consonance, Memory and Time
revised	1924	10yr~adults	60 min.	+Rhythm
revised	1960	10yr~adults	60 min.	Pitch, Loudness, Rhythm, Time/Duration, Timbre and Tonal memory
Kwalwasser-Dykema Music Tests	1930	10yr~adults	60 min.	Similar to Seashore test. Movement, Melody, Intonation and The image of Rhythm were added
Drake Music Tests	1954	8yr~adults	20 min. each	Rhythm and Memory
Wing Standardised Tests of Musical Intelligence	1948	8yr~adults	60 min.	Harmony analysis, Pitch, Memory, Rhythm, Harmony, Loudness and Phrasing
Gaston Test of Musicality	1958	10yr~18yr	40 min.	Musical interest, Harmony, Rhythm, Pitch and Tonal memory
Bentley Measure of Musical Abilities	1966	7yr~14yr	20 min.	Pitch, Tonal Memory, Rhythm memory and Harmony analysis
Gordon Musical Aptitude Profile	1965	Grade 4~12	50 min. each	Tonal imagery, Rhythm and Musical Sensitivity
Primary Measures of Music Audiation	1986	K~grade 3	20 min. each	Tonal imagery and Rhythm

* Year that the test was developed.

ers of the three mainstream pre-schools, and to the children who attended the preschools and their parents. Even if it seemed that the child would not understand the explanation and the child did not express himself/herself with words yet, the study was orally explained to each child and his/her parent. Written detailed explanations of the study were also given to the directors and teachers of the three preschools and to the parents. The director of each pre-school confirmed which parents consented to allowing their child to participate in the study and provided written informed consent on behalf of the children at that pre-school.

Procedure

Since a strict experimental laboratory setting would scare the children, the children were tested in a classroom of the preschool that they attended. Testing was performed in a classroom of the preschool with which the child was familiar, to make it as natural and comfortable for the child as possible. It has been pointed out that the results of studies on children that are conducted in an artificial setting often differ from those conducted in a natural setting [14].

Following is the test procedure that was used for the children aged 6 months to 12 months. The child went into the preschool classroom with his/her mother or a pre-school teacher. The classroom was a room that the child normally uses. Then, the examiner sat on a chair facing the child and started to clap. The examiner did not give verbal instructions to the child, nor did the examiner perform practice sessions with the child before the actual testing. The reason why the mother or teacher was permitted to accompany the child during testing is that some of the babies were not strong enough to sit up by themselves, while other children felt quite nervous and anxious if he/she was left alone with the examiner. The mother or teacher was instructed not to give any advice or help to the child.

Following is the test procedure that was used for children who were older than 12 months of age. A group of 5 children went into a preschool classroom that they normally use and each child sat down on a chair. The chairs were arranged in a semi-circle with sufficient space between the children (approximately 2 m 50 cm between adjacent children). The examiner sat in front of them on a chair. The examiner directly faced one child and started to clap. The examiner did not provide verbal instructions, nor did the examiner perform practice sessions prior to the actual testing. When the testing on one child was completed, the examiner shifted her sitting position on the chair to directly face the next child and began to clap. When a child was being tested, two teachers silently played with the four children who were not being examined, thereby minimizing the possibility that the other children learned the task in the short period of time before being examined. Testing was performed in the presence of other children and teachers so that the child who was being examined would not feel nervous and would feel comfortable, and it became possible to observe his/her responsiveness in a condition similar to that in the everyday classroom. Testing was performed under these conditions to avoid inaccurate assessment of the musical responsiveness of the children due to fear and tension that the children may have felt when meeting the examiner for the first time.

In order to prevent observational learning, the following 4 controls were employed. First, children who were taking or had taken music lessons were excluded from this study as described earlier in the "Participants" section, because children who had taken music lessons possibly had a mode

of phonic dictation different from that of other children, and such difference was considered to influence musical responsiveness. Second, the innate responsiveness of children was assessed when the children were in an environment similar to that of their regular classroom. If each child had been tested alone in an examination room while directly facing the examiner whom he/she met for the first time, the child probably would have felt fear and tension. Testing the children in an environment similar to that of their regular classroom was particularly important in the present study, in which testing was performed in a short period of time without verbal instructions, and consequently there was no rapport between the subjects and the examiner. Third, the subjects, their parents, and teachers were not informed beforehand of details of the tasks used in this study. The tasks were presented to the subjects for the first time at the time of testing. This procedure made it possible to prevent teachers and parents from practicing the tasks with the children in advance, and the innate musical responsiveness of the children could be observed at the time of testing. Fourth, since the individual tasks contained musical elements, a child was not considered to have accomplished a task if he/she made simple behavioral movements as described in the Test battery section below. In other words, each Rhythm task was composed of several sequential patterns of different rhythms, and a subject who made a simple movement, such as placing his/her hands together or hand clapping, was not considered to have accomplished the task. The Melody tasks were composed of different patterns with musical intervals, and a child who made a simple vocalization was not considered to have accomplished the task. In addition, two observers independently viewed videotapes of the testing sessions and verified the judgment of the examiner as to whether the musical responsiveness of each child observed during the testing session did or did not represent simple learned behaviors. By adopting these four conditions, the subjects were prevented from learning the test tasks before the actual testing. Dictation ability cultivated by training was also prevented from influencing the musical responsiveness of the subjects. The four conditions were determined so that the responsiveness observed at the time of testing directly represented the innate musical responsiveness of the subjects without modification.

During the testing of each child, the examiner observed the child to see whether the child correctly imitated each individual tone or series of tones that had been delivered by clapping or by the voice of the examiner. After the examiner who had perfect pitch delivered a pattern by either clapping or voice, the examiner judged whether the child had imitated the pattern accurately. If the child imitated a tone incorrectly, the examiner delivered that particular tone again up to five times. If the child could not imitate a pattern within 5 trials, it was considered that the child could not imitate that pattern. Then, the examiner presented the next pattern. After the examiner delivered each pattern to a child, the examiner wrote down whether the child correctly imitated the pattern or not. The testing sessions between the examiner and each child were videotaped, and the examiner viewed the videotape to double-check whether the child could or could not imitate each pattern. After the examiner viewed the videotapes and assigned whether the children could or could not imitate each pattern, all of the judgments were the same as the real-time judgments.

Based on previous studies, special attention was paid to the following points while conducting this study.

- In the Melody section, absolute pitch was secondary to the interval in the child's responses. Namely, the examiner and observers were instructed to focus on whether the child could reproduce the interval, rather than the given absolute pitch [15–23].
- The voice range between D and A was chosen because it fits most comfortably in the natural vocal range of young children, as indicated in previous studies on the development of vocalization in children [24–27].

Test battery

The test that was developed was named the Non-Verbal Measurement of the Musical Responsiveness of Children (Non-Verbal MMRC).

The test battery of the Non-Verbal MMRC was developed according to the results of previous studies on the musical development of infants and children [17,28–33]. The Non-Verbal MMRC is made up of the Rhythm section and Melody section, which consist of the following items.

Rhythm section:
1. Single quarter note;
2. Sequential two quarter notes;
3. Sequential three quarter notes;
4. Single quarter note – Sequential two eighth notes – Single quarter note;
5. Triplet – single quarter note;
6. Dotted notes – single quarter note;
7. Sequential four sixteenth notes – single quarter note.

Melody section:
1. Single quarter note;
2. Major 2nd (down);
3. Major 3rd (down);
4. Contour schemes of major 2nd (down-up);
5. Contour schemes of major 3rd (down-up);
6. Contour schemes of major 3rd (circulation).

The examiner presented the 7 patterns in the Rhythm section by clapping, and the 6 patterns in the Melody section by voice. The examiner presented the patterns in the order shown in the list to each child.

The correlation between the results obtained with the music protocol and the results of an accepted developmental test was examined. For this purpose, the standard pediatric developmental scale named "the New Edition of the Kyoto Scale of Psychological Development" (the new edition of the K-format test) was used. The reliability and scientific validity of this test have been assessed using data obtained from a total of 1562 children during the period from 1979 to 1981, and the test was standardized in 1983 [34–37]. The new edition of the K-format test had been constructed according to the tests of Gesell [38], Buhler [39], and Binet [40]. In Japan, the new edition of the K-format test is frequently administered to pediatric patients at medical and health-care institutions, and is occasionally utilized during the health check-up of 1.5-year-old children for early detection of developmental delay. Each examined item belongs to one of the following three areas: (1) postural-mo-

tor area, (2) cognitive-adaptive area, and (3) language-social area. Based on the results of this test, values of the developmental age (DA) and developmental quotient (DQ) are calculated. Whereas the chronological age (CA) indicates the actual age, the DA indicates the age of ordinary children whose development is comparable to that of the child being examined. The DA can consequently be an indicator of development. As mentioned earlier, children who were found to be at risk for pervasive developmental disorder based on the results of the new edition of the K-format test, were excluded from this study. The correlations between the Melody or Rhythm scores on the Non-Verbal MMRC and DA were examined.

Reliability

The testing sessions between the examiner and each child were videotaped as mentioned above. The accuracy of whether the children imitated the patterns was re-judged by two observers who each independently viewed the videotapes and assigned scores as to whether the child could or could not imitate the patterns. Observers with perfect pitch were selected by asking individuals to take the following test. The investigator played the following intervals, chords, scales and modes on a very well-tuned piano, and the individuals were asked to answer what they were:

1. major second;
2. minor second;
3. major third;
4. minor third;
5. perfect fourth;
6. perfect fifth;
7. diminished seventh;
8. major triad;
9. minor triad;
10. a major scale;
11. church dorian mode;
12. church aeolian mode.

Two individuals who could answer all items perfectly were selected to be observers.

The observers were informed of how the music test was conducted with the children. Each observer watched the videotapes of the testing sessions of 28 randomly chosen children and assigned scores for each child as to whether the child could or could not imitate each pattern.

Statistical analysis

Each pattern that the child could imitate was assigned a score of one. The 7 patterns in the Rhythm section and the 6 patterns in the Melody section had been chosen based on several studies and theories about the appearance of children's musical expression. The items in the Rhythm or Melody section were selected so that pattern 2 is more difficult than pattern 1, pattern 3 is more difficult than pattern 2, and so on. It was considered whether to assign higher scores for correct imitations of more difficult patterns. The following scoring system was considered: if a child could imitate pattern 1, a score of 1 is given; if a child could imitate pattern 2, a score of 2 is given; and so on. However, during the observations of the children, it was difficult to determine whether the major 2nd was easier to imitate than the major 3rd, and so on. Therefore, it was decided that a score of 1 would be assigned for each pattern that was correctly imitated, and a score of 0 would be assigned for each pattern that was not correctly imitated or if there was no response from the child.

The total score in the Rhythm or Melody section was the sum of the scores on the patterns in the respective section. Therefore, the maximum total score in the Rhythm section for a subject was 7, and the maximum total score in the Melody section was 6. Plots of the Rhythm or Melody score versus the DA (in years) among the 92 subjects are shown. The DA was shown in years in these graphs to simplify the graphs. Correlation analyses between the Rhythm or Melody score on the Non-Verbal MMRC and the DA (in months) that had been calculated from the new edition of the K-format test, were performed with Spearman's correlation. To assess the inter-rater reliability among the three raters, Kendall's W test was used. $P<0.05$ was considered to indicate statistical significance.

RESULTS

The innate musical responsiveness of ninety-two children between the ages of 6 months and 69 months was tested with the Non-Verbal MMRC, and their Melody and Rhythm scores were analyzed. Figures 1 and 2 show plots of the Rhythm or Melody score versus DA (in years) among the subjects, respectively. Infants under 10 months of age did not show responsiveness to any of the musical patterns in the Rhythm section. Infants began to show responsiveness to rhythm and melody at 12 months of age. Starting at approximately 45 months of age, some children were able to imitate all seven patterns in the Rhythm section perfectly. Then, by the age of 69 months, there was a tendency that the majority of subjects imitated all of the patterns in the Rhythm section perfectly.

As to the Melody section, children under 10 months of age did not show any responsiveness, similar to the Rhythm section. In the Melody section, children started to show responsiveness at approximately 12 months of age. Perfect scores in the Melody section were observed at 27 months of age at the earliest. The majority of children older than 60 months had a score of 5 or 6 out of a maximum score of 6.

Correlation analyses between the results on the Non-Verbal MMRC and the developmental age (DA, in months) calculated from the new edition of the K-format test, were performed. There was a significant correlation between the total score on the Rhythm section of the Non-Verbal MMRC and DA among the 92 children ($R=0.81$; $P<0.001$). There was also a significant correlation between the total score on the Melody section and DA among the 92 children ($R=0.63$; $P<0.001$).

The inter-rater reliability among the examiner and 2 observers was assessed. The two observers independently viewed videotapes of the testing sessions and assigned Melody and Rhythm scores for 28 randomly selected children. Kendall's W test revealed high reliability among the scores of the examiner and the two observers (for Rhythm scores, Kendall's $W=0.95$, $p<0.001$; for Melody scores, Kendall's $W=0.78$, $p<0.001$).

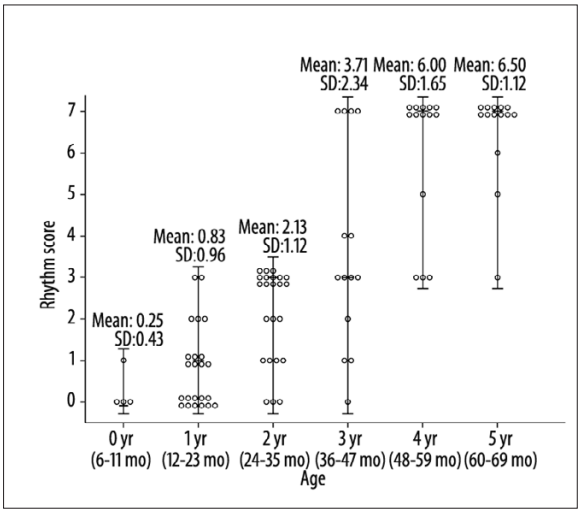

Figure 1. Distribution of the Rhythm scores on the Non-Verbal MMRC of the 92 normal children according to age. The subjects were categorized according to yearly age for simplicity. The horizontal bars show the mean and standard deviation. The monthly age of the children ranged between 6 months and 69 months. Correlation analyses between the Rhythm score and monthly age among the 92 subjects revealed R=0.81, p<0.001.

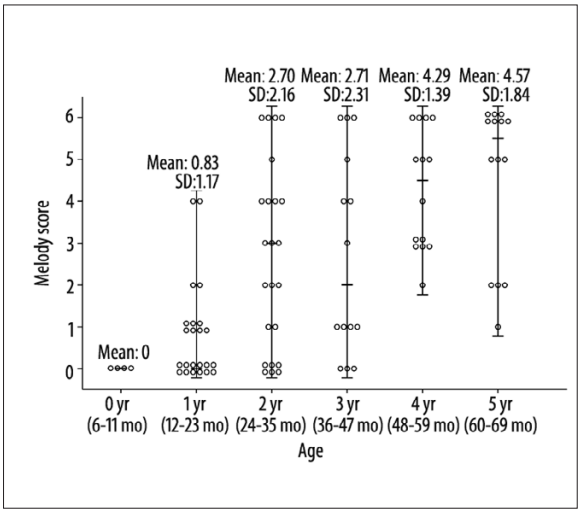

Figure 2. Distribution of the Melody scores on the Non-Verbal MMRC of the 92 normal children according to age. The subjects were categorized according to yearly age for simplicity. The horizontal bars show the mean and standard deviation. The monthly age of the children ranged between 6 months and 69 months. Correlation analyses between the Melody score and monthly age among the 92 subjects revealed R=0.63, p<0.001.

Discussion

The results of this study showed that musical responsiveness is closely correlated with the general developmental age among normal children. Children began to imitate rhythms and sing an accurate contour melody line at approximately 12 months of age. Thereafter, musical responsiveness developed as the child grew older and the majority of children could imitate all patterns in the Rhythm and Melody sections of the Non-Verbal MMRC by 5 years of age.

During the testing sessions, some of the children aged 8 to 24 months seemed to refuse to respond or seemed to pretend to not be able to respond, although it was thought that they had the ability to respond based on discussions with their teachers. This phenomenon may reflect stranger anxiety in child development psychology which was discussed by Spitz [41], because these children showed this behavior during their interaction with the examiner although it was thought that they could accomplish the tasks. This behavior was observed starting at around 8 months of age.

The method developed in this study makes it possible to assess the developmental state of children from the viewpoint of music responsiveness, which has hitherto been neglected in constructing tests that assess the development of children. The Non-Verbal MMRC can be administered to children who do not yet understand verbal instructions and to children who cannot make verbal responses. Therefore, this method can be administered to subjects whose development cannot be studied with the developmental scales used at the present time including very young children at the nonverbal and pre-verbal stages and children with special needs. This test can be administered to early age children including those under the age of 1 year, and does not require a verbal circuit in the subjects. Therefore, this method seems to be valuable. This method has another advantage. Since the results of the test are the behavioral responses of the child, the differences in the standard of judgment among examiners are small. An additional advantage of this method is that assessment does not partly depend on information provided by the child's parents. Consequently, this test enables us to comprehend the unmodified state of children accurately by directly observing their behaviors.

Since the testing session of currently-used test batteries usually lasts a long period of time, children often fail to maintain their concentration throughout the testing session. This situation can influence the results of the tests. The Non-Verbal MMRC was designed so that the testing session could be completed within a time period during which the child could maintain his/her concentration unabated. Therefore, testing with the Non-Verbal MMRC is expected to yield more accurate results on the general development of individual children. In addition, children are observed directly through the musical protocol in this study, and the scores do not partly depend on information provided by their parents. This feature of the Non-Verbal MMRC leads to more accurate results on young children than those obtained in the currently-available developmental tests.

In this study, the Melody and Rhythm scores of the Non-Verbal MMRC were each significantly correlated with the developmental age as assessed by the new edition of the K-format. This indicates that musical responsiveness develops in a similar pattern as language, motor and cognitive abilities. Additionally, upon analysis of the inter-rater reliability, the magnitude of the variation in scores given to each child was small among the examiner and the two observers, suggesting that data obtained with the Non-Verbal MMRC are highly reliable.

Using the Non-Verbal MMRC, it will be possible to perform various studies on healthy children at the pre-verbal stage, i.e., children in developmental stages before they have acquired linguistic ability. When such studies are performed using currently-available general developmental tests, the test items must be chosen according to the child's age, and the content and form vary depending on the age of the subjects. Several test forms are included in one developmental test. In addition, these tests cannot be administered to very young children [42]. With the Non-Verbal MMRC, studies on healthy children at the pre-verbal stage can be performed without modifying the test. Therefore, this test is expected to provide more accurate data on healthy children, as well as data on children with developmental delays who have been excluded from academic studies on child development.

With the Non-Verbal MMRC, it may be possible to assess the development of children with special needs. It has been difficult to select a test battery that is appropriate for examining the musical responsiveness of subjects who are of advanced chronological age but delayed in developmental age, i.e, those who are delayed for their actual age due to some handicap. The Non-Verbal MMRC can be administered to children with special needs who cannot understand verbal instructions and cannot understand the meaning of tasks, as well as to children who can understand verbal instructions but cannot reply verbally. In other words, this test provides a tool for examining the musical responsiveness as well as the general development of children independent of the verbal circuit in the brain, and can be used to study subjects in whom musical responsiveness could not be studied in the past.

It may also be possible to use the Non-Verbal MMRC to develop new music therapies for children with special needs including children who have a handicap in language, recognition or movement and who had not been benefiting from general therapeutic interventions such as occupational therapy, physiotherapy, and speech therapy, or on whom such intervention conceivably would have no effect. It may be possible to assess the musical responsiveness of these children with the Non-Verbal MMRC, and based on the level of musical responsiveness, methods of musical intervention may be developed to activate remnant functions or to trigger acquisition of functions that have not yet been acquired.

Music has recently attracted considerable attention as a therapeutic medium. Listening to music induces positive emotions and removes anxiety and stress. The effects of listening to music on various biological markers of stress (changes in plasma signal molecules involved in peripheral blood pressure [43] and nitric oxide levels [44]) have also been studied. Subjects who were exposed to their preferred musical selections had significant reduction of anxiety levels [45]. With continuing efforts to elucidate the physiological effects of music, the use of music as medical treatment may expand. If the musical responsiveness of people with special needs can be clarified with the Non-Verbal MMRC devised in this study, it may be possible to use music as therapeutic intervention. The present study may play a role as a bridge between the physiological studies enumerated above and the clinical application of music in the future.

CONCLUSIONS

The degree of musical responsiveness as measured by the Non-Verbal MMRC was highly correlated with the DA among normal children. The interaction between music and children's social development has been discussed [46]. However, musical responsiveness has not been considered as an index in the development of children. The currently-available general developmental test batteries focus on assessing the motor, cognitive and language functions of children. Similar to motor ability, cognitive and language, the degree of musical responsiveness was correlated with developmental age among early age children. Additionally, the reliability of this non-verbal measurement tool was verified.

Using the Non-Verbal MMRC, the musical responsiveness of infants and young children who do not yet have the ability to understand verbal instructions and who are not capable of providing verbal answers can be assessed. The Non-Verbal MMRC may also be administered to children with special needs who are at the pre-verbal or non-verbal stage.

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