Assessment of the Tongue’s Stereognostic Ability of Healthy Subject in the Absence of Visual Reference Objects

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Abstract

The aim of the present study was to examine the tongue’s stereognostic ability of healthy subject in the absence of visual reference objects. The stereognostic ability of the tongue was assessed by placing 10 different test pieces in the mouth, and subjects were asked to draw the shape of each test piece in their mouths, and the drawings were scored. The average score was 15.6 of 30 possible points, and scores varied among individuals. For comparison, the stereognostic ability was also measured in the presence of visual references; subjects were asked to choose the corresponding shape to each test piece in their mouths among presented pictures of the test pieces. The mean number of correct answers was 9.2 of 10 possible numbers; the presence of visual references dramatically increased the correct response rate and decreased individual variability.

To examine what were other tongue functions needed for stereognosis, two-point discrimination and motor ability of the tongue were also investigated. Two-point discrimination was assessed by touching one or two points with fixed distances to the tongue, and asking the subjects to identify how many points were contacted. To assess motor activity, the time to turn over a test piece in the mouth by the tongue was measured. The stereognostic ability of the tongue in the absence of visual references was not correlated significantly with two-point discrimination or the time to turn over a test piece.

In conclusion, the assessment in the absence of visual references could detect individual differences in stereognostic ability of the tongue in more detail than the assessment in the presence of visual information. The assessment method without visual information would be helpful in the diagnosis and treatment of patients with dysphagia.

Introduction

Somatic and taste sensations of the tongue play an integral role in eating and swallowing. Quantitative measurement of these sensory functions is important in the diagnosis and treatment of patients with dysphagia [1]. As one of these oral sensations, oral stereognostic ability to identify the shape of a object in the mouth has been studied greatly because the shape and size of an intra-oral bolus of food provides oral sensory information important for eating and swallowing [2,3]. In the studies measuring oral stereognosis, subjects were asked to identify the shapes of objects placed in their mouths from duplicated test pieces or pictures of the test pieces presented in front of them [2-8]. The studies demonstrated high oral stereognostic ability, which was dependent on the tongue, and decline in the ability with age [9-12].

However, it remains to be clarified whether humans are able to recognize the shape of test pieces by the tongue when referential shapes are not presented visually as few reports have been published on oral stereognosis without use of visual reference objects. In the present study, we attempted to measure the tongue’s stereognostic ability in the absence of visual reference objects and compare with the activity in the presence of visual reference using the test pieces used in our previous study [11,12].

Furthermore, to examine other tongue functions which were needed for stereognosis being referred to as a high-order sensory function, two-point discrimination, a low-order sensory function was measured. Additionally, the tongue’s motor function was also examined, due to the need of test piece manipulation in the mouth for stereognosis.

Materials and Methods

Subjects

The subjects were 19 young adults (students of Kyushu Dental University; 10 males, 9 females; mean age: 23.3 years; age range: 22 to 26 years) without masticatory or swallowing dysfunction. Approval for the study protocol was obtained from the ethics committee of Kyushu Dental University. Written consent was obtained from all subjects following sufficient explanation of the purpose and content of the research.

Stereognostic Ability of the Tongue

To assess the stereognostic ability of the tongue, we used a method whereby the shape of various test pieces were evaluated intra-
orally, as previously described [11]. Data obtained by this method was attributed to the stereognostic ability of the tongue, because it has already been reported that covering the palate does not affect oral stereognostic ability [11-15].

We assessed stereognostic ability under two conditions: in the absence or presence of visual reference objects, which are referred to as Tests 1 and 2, respectively. The 10 different-shaped polyethylene test pieces (13-mm length, 2-mm thickness) used in the tests are shown in Figure 1. A fine thread (diameter: 0.2 mm) was attached to each test piece to prevent choking.

The test procedure was as follows. In Test 1, the examiner first asked the subjects to visually check the shape and size of a square test piece (test piece No. 7) and informed them that the longest dimension of each test piece was 13 mm. Next, with their eyes closed, the subjects stuck out their tongue, and one of the 10 test pieces was placed on the middle of the tongue. The subjects were then asked to move the piece in their mouths without letting it touching their teeth or gums to determine its shape, and then to draw the shape of the test piece in a 13-mm square box. The test was completed when all 10 different test pieces had been evaluated in the same manner. The drawings were scored using a four-point
A drawing with approximately the correct shape and size was scored as three points, a drawing with approximately the correct shape and incorrect size, or with approximately the correct size and overall incorrect shape but showing the correct shape characteristics, such as convex or concave curvature or projection, was scored as two points, a drawing with approximately the correct shape or having the correct shape characteristics but with incorrect size was scored as one point, and an incorrect identification of shape and size was scored as zero. If all answers were correct, a full 30 points were scored. Two rater scored simultaneously. In Test 2, instead of drawing the shape, the subjects were asked to choose the corresponding shape to each test piece in their mouths from among pictures of the 10 test pieces; choosing the same test piece multiple times was not prohibited.

Tests 1 and 2 were carried out in the same subject immediately, without a rest period. In both tests, the subjects were not informed whether or not their responses were correct. The order in which the 10 test pieces were presented was the same in all subjects, indicated by test piece number. The 10 test pieces consisted of shapes from simple to complex, and were selected from among the 20 different-shaped test pieces used in our previous study [11]. Ten test pieces, rather than 20, were used to avoid confusion for the subjects when without visual reference, due to the subtle differences between the 20 test pieces.

**Two-Point Discrimination**

Two-point discrimination was measured by touching the tongue with either one or two points with fixed distances, and asking the subjects how many points were contacted. The fixed distances (2 and 4 mm) between the two points of the tools were determined by reference to the study of Premkumar et al. [16]. Two-point discrimination was performed on the tip of the tongue, the center of the dorsum 2 cm away from the tip, and on the right and left lateral margins 2 cm away from the center of the dorsum. Because it has been reported that instrument material had little effect on point discrimination [8], we used a tool made from wooden toothpicks.

**Motor Ability**

Motor ability was assessed by measuring the time to turn over a test piece in the mouth using the tongue. As differences in shape and size may affect the turn-over time, the time to turn over the four test pieces Nos. 2, 4, 7, 10 was measured. The 4 test pieces were selected on the basis of different shape and size (the contact area for the tongue) from the 10 test pieces used in the assessment of stereognosis, The time to turn over a test piece five times was measured because the time to turn over a test piece one time was too short to difficult to measure properly.

**Statistical Analysis**

The significance of differences between two groups was analyzed by the unpaired Student’s t-test for equal variance or Welch’s correction for unequal variance using Ekuseru-Toukei 2010 (Social Survey Research Information Co., Ltd., Tokyo, Japan). For comparison among more than 3 independent groups, Tukey’s HSD (for homogeneous variance) or Dunnet’s method (for inhomogeneous variance) was performed using SPSS Statistics 19 (IBM Japan, Tokyo, Japan). The coefficient of correlation of two variables was calculated also by using Ekuseru-Toukei 2010.A p-value<0.05 was considered significant.

**Results**

**Stereognostic Ability in The Absence of Visual Reference Objects**

The drawings and stereognosis scores in Test 1, which were performed in the absence of visual reference, are shown in Fig. 2. The mean score and range were 15.6 ± 6.0 (Mean ± SD and 7–26, respectively. The proportion of subjects who scored 2 or 3 for each of the test pieces are shown in Table 1. Approximately 70–80% of subjects identified the exact shape and size of the two quadrangle-shaped and circle-shaped test pieces (Nos. 2, 4, 7). The second most easily identifiable test pieces were the two triangle-shaped pieces (Nos. 1, 6). Sixteen of the 19 subjects (84%) identified these test pieces as triangles; however, the proportion of subjects who scored a 3 for pieces No. 1 and 6 were low, at 47% and 37%, respectively, because many subjects were unable to indicate the correct size. The shape and size of test piece No.5, which has an indented section within a square shape, were correctly identified by six subjects. Although the remaining twelve subjects’ scores were either low or zero, they were still able to identify the indented feature. The shape and size of test piece No.9, which also has an indented section within a circle shape, was correctly identified only by one subject; the other subjects identified the indented section, but were unable to identify the shape of the whole piece. Eight subjects recognized the narrowness in the middle of test piece No. 10, although they were unable to identify the correct size. Only two subjects correctly identified test piece No.8, which was similar to test piece No.2, but with rounded off corners; other subjects described shapes similar to No.2 or a smaller size. Only one subject correctly identified the cross-like test piece No.3. Half of the subjects described it as a star-like shape, and the remaining subjects could detect the edges but not the shape.

**Stereognostic Ability in The Presence of Visual Reference Objects**

The proportion of correct answers (correct response rate) for each of the 10 test pieces in Test 2 are shown in Table 1. Eight of the 19 subjects identified all 10 test pieces correctly, and the mean number of correct answers was 9.2. Most misidentifications were due to an inability to distinguish between the two triangle test pieces, No.1 and 6. Seven of the 8 subjects who misidentified test piece No.1 instead identified it as No.6. Misidentification of No.9 for No.5, both with indented portions, also occurred.

**Two-Point Discrimination**

Table 2 shows the incorrect responses of each subject for each question asking how many points were contacted. The highest correct response frequencies were obtained at the tip of the tongue; 74% and 95% of subjects were able to correctly identify two separate
### Table 1: Identification results of stereognostic ability tests in the absence and presence of visual reference objects.

| Test pieces | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| A-1         | 9 (47) | 16 (84) | 1 (5) | 13 (68) | 6 (32) | 7 (37) | 13 (68) | 2 (10) | 1 (5) | 5 (26) |
| A-2         | 11 (58) | 18 (95) | 4 (21) | 13 (68) | 8 (42) | 10 (52) | 14 (74) | 4 (21) | 8 (42) | 7 (37) |
| B           | 11 (58) | 19 (100) | 19 (100) | 18 (95) | 19 (100) | 16 (84) | 18 (95) | 19 (100) | 17 (90) | 19 (100) |

A-1; in the absence of visual information, the numbers and percentages of subjects who scored 3 for each of the 10 test pieces. Upper, number; lower (shown in parentheses), percentage.

A-2; in the absence of visual information, the numbers and percentages of subjects who scored higher than 1. Upper, number; lower (shown in parentheses), percentage.

B; in the presence of visual information, the numbers and percentages of individuals who answered correctly (correct response rate) for each of the 10 test pieces. Upper, number; lower (shown in parentheses), percentage.

### Table 2: Incorrect identification of contact points for each subject in two-point discrimination test.

| B | 1-point | 2-point (2mm) | 2-point (4mm) |
|---|---------|---------------|---------------|
|   | rm      | c | lm | t  | rm | c | lm | t  | rm | c | lm | t  |
| 1 | 1       | 1 | 1  | 1  | 1  |
| 2 | 1       | 1 | 1  | 1  | 1  |
| 3 | 1       | 1 | 1  | 1  | 1  |
| 4 | 1       | 1 | 1  | 1  | 1  |
| 5 | 1       | 1 | 1  | 1  | 1  |
| 6 | 1       | 1 | 1  | 1  | 1  |
| 7 | 1       | 1 | 1  | 1  | 1  |
| 8 | 1       | 1 | 1  | 1  | 1  |
| 9 | 1       | 1 | 1  | 1  | 1  |
| 10| 1       | 1  | 1  | 1  | 1  |
| 11| 1       | 1  | 1  | 1  | 1  |
| 12| 1       | 1  | 1  | 1  | 1  |
| 13| 1       | 1  | 1  | 1  | 1  |
| 14| 2       | 1  | 1  | 3  | 1  |
| 15| 1       | 1  | 1  | 1  | 1  |
| 16| 1       | 1  | 1  | 1  | 1  |
| 17| 1       | 1  | 1  | 1  | 1  |
| 18| 1       | 1  | 1  | 1  | 1  |
| 19| 2       | 1  | 1  | 3  | 1  |

CER(%): 94.7 100 84.2 94.7 26.3 31.6 10.5 73.7 52.6 63.2 52.6 94.7

Values indicate incorrect answers provided by subjects for the number of contact points.

A: Actual number of contact points. rm: right lateral margin; c: center of dorsum; lm: left lateral margin; t: tip. B: subject. CER (%): correct response frequencies.
contacts separated by distance of 2 mm and 4 mm, respectively. Compared with the tip, other regions showed very low rates of correct answers, with 11~32% and 53~63% of subjects correctly identifying two separate contacts of a distance of 2 mm and 4 mm, respectively. Correct response frequencies were lower when the two points were separated by a distance of 2 mm compared with 4 mm in every region. A few subjects overestimated the number of contact points and answered two points when contacted by one point, or three points when contacted by two points. Only one of the 19 subjects identified each contact correctly. The degrees of two-point discrimination correctness were correlated poorly with the stereognosis scores in the absence of visual information (correlation coefficient 0.308).

Motor activity

The mean times to turn over four different test piece 5 times in the mouth by the tongue are shown in Table 3. There were no differences in time to turn over the test pieces among each of the four test piece or between genders. The times to turn over four test pieces were not correlated significantly with the stereognosis scores in the absence of visual information (correlation coefficient -0.031~ -0.214).

| Test piece |
|------------|
| Gender     |
| 2          |
| 4          |
| 7          |
| 10         |
| Male       |
| Female     |
| Total      |

Values: seconds (Mean ± SD). Numbers shown in parentheses are the ranges.

Discussion

Stereognostic Ability in the Absence of Visual Reference Objects

Berry and Mahood have suggested that Crossman was likely the originator of the oral stereognosis tests to assess oral perception [17,18]. Studies on oral stereognosis gained significance after it was discovered that people with deficiencies in their oral sensory functions were also afflicted by speech and mastication disorders [19,20]. In the clinical setting, it is necessary to quantitatively evaluate sensory activity. In previous studies measuring oral stereognosis, subjects were asked to identify the shapes of objects presented intra-orally from duplicated test pieces or pictures of the test pieces presented in front of them, and high oral stereognostic ability was demonstrated [10-19]. It has also been reported that there are no gender differences [6,11,21]. In our previous studies, using 20 or 6 different-shaped test pieces, we further demonstrated that the stereognostic ability of the tongue declines with age, and we suggested the possibility of recovering this ability using our training method [11,12].

However, it remained to be clarified to what degree humans are able to recognize the shape of test pieces only by the tongue, in the absence of visual information of the test piece shapes. Previously, Laine et al. examined oral stereognosis without visual references of the shapes, and reported that the mean stereognosis score was 39.5 of 60 possible points [20]. However, their test pieces and scoring method differed from ours, and detailed data on correct response rates and drawings by the subjects for each test piece were not shown. Therefore, we investigated the stereognostic ability of the tongue in the absence of visual reference objects using 10 different-shaped test pieces with different characteristics. Simple polygonal and circular-shaped test pieces were recognized easily, although they may not had been drawn perfectly. For more complex test pieces, features such as indentations or protrusions could be identified, but the entire shape was unable to be drawn. In the stereognosis score, the highest and lowest total scores were 26 and 7 points of 30 possible points, respectively. The number of subjects with accuracy rates greater than 50% (score of 15 or higher), greater than 40%, and less than 40% were 10, 4, and 5, respectively, demonstrating that the stereognostic ability in the absence of visual reference varied among the subjects. These differences may reflect differences among the subjects in their ability to imagine the shape of an object. We have previously shown using functional near-infrared spectroscopy in young adults that during oral stereognostic cognitive processes, blood flow increased in the frontal cortex, including the prefrontal area, but shows large individual variability [22].

Table 3 Times to turn over test pieces in motor ability test.
Stereognostic Ability in the Presence of Visual Reference Objects

We have also previously reported that using the traditional methods to measure the tongue’s stereognostic ability with visual information in young adults, the mean correct number of responses for 20 test pieces was 16.5, and that of the assessment using 6 test pieces was 94.9% [11,12]. Consistent with the above results, in the present study, most of the young adult subjects could recognize all test pieces perfectly when using 10 test pieces. Comparing the results with those from the assessment in the absence of visual information, presence of visual reference for differential identification dramatically increased correct response rate, and decreased individual variability. Interestingly, there were also instances of misidentification of simple-shaped test pieces.

Two-Point Discrimination

It has been suggested that stereognosis is dependent on active touch, and comprehensively reflects multiple functions of the tongue, such as proprioceptive sensation, skilled motor activity, and material-searching ability, and may also be dependent on oral environment [23]. To elucidate the association between oral stereognostic ability and these multiple component factors, we investigated the ability to discriminate between two points touched on the tongue, which is passive touch. Two-point discrimination has been performed for assessment of oral sensation in many previous studies [6,8,24]. Rather than measuring the threshold of two-point discrimination using dividers, we touched the tongue at one or two points with fixed distances (2 or 4 mm), and asked the subjects how many points were contacted. The present results showed that the accuracy of two-point discrimination differed among each subject. However, the area with the highest rate of correct discrimination was the tip of the tongue, followed by the center of the dorsum and the lateral margins, consistent with previous reports [16,24,25]. The stereognosis scores in the absence of visual information were not correlated significantly with the degree of two-point discrimination correctness (correlation coefficient 0.308), consistent with a previous report by Laine et al. [20]. The association between stereognosis ability in the presence of visual information and two-point discrimination could not be assessed because there were no individual differences in the stereognostic activities among the subjects.

Motor Ability

In addition to sensory components, a certain amount of motor activity is involved in oral stereognosis due to the need to manipulate the test pieces in the mouth [9,13,26-28]. To clarify the association between oral stereognosis and motor activity, tongue motor activity was assessed by manipulating a test piece in the mouth. Some previous studies have evaluated motor activity by measuring the time to orally assemble two different halves of a test piece [27,29]. However, this method is too complicated to apply to the elderly and patients with a swallowing disorder. Therefore, we assessed the tongue’s manipulation ability by measuring the time to turn over a test piece in the mouth as a simple method of assessment. There were no differences in times among the subjects. As there were no differences in time to turn over the test pieces among each of the four test piece, in future studies only one test piece maybe enough to assess turn-over- time, but the shape and size may have effects on turn-over-time in the elderly and patients with deglutition disorders.

Future studies

Assessment in the presence of visual information has previously shown that the tongues’ stereognostic ability decreased with age, and that the ability level of elderly receiving care was lower [10-12]. The tongues’ stereognostic ability in the absence of visual reference in the elderly and patients with deglutition disorders remains to be clarified. Future studies in the elderly and patients with deglutition disorders to investigate the changes and associations among stereognostic ability in the absence of visual reference, two-point discrimination, or motor activity of the tongue are warranted.

Conclusion

Compared to the assessment of stereognostic ability of the tongue in the presence of visual information, the absence of visual reference dramatically decreased the correct response rate, and increased individual variability. It suggests that the assessment of stereognostic ability of the tongue in the absence of visual reference could detect individual differences in the ability in more detail than the assessment in the presence of visual reference. The assessment method without visual information might contribute to detailed analysis of stereognostic ability of the tongue and be helpful in the diagnosis and treatment of patients with dysphagia.

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References

1. Logemann JA (1998) Evaluation and treatment of swallowing disorders – 2nd ed. Austin: TX PRO-ED.
2. Jacobs R, Serhal CB, van Steenbergh D (1998) Oral stereognosis: a review of the literature. Clin Oral Investig 2(1): 3-10.
3. Boliek CA, Rieger JM, Li SY, Mohamed Z, Kicckham J, et al. (2007) Establishing a reliable protocol to measure tongue sensation. J Oral Rehabil 34(6): 433-441.
4. Arndt WB, Elbert M, Shelton RL (1967) Standardization of a test of oral stereognosis. In: Second symposium on oral sensation and perception (ed. by Bosma, J.F.) . Springfield, Illinois: Charles C. Thomas. 379-383.
5. Catalanozzo FA, Moss JL (1973) Manual and oral stereognosis in children with cleft palate, gonadal dysgenesis, pseudohypoparathyroidism, oral facial digital syndrome and Kallman’s syndrome. Archs Oral Biol 18(10): 1227-1232.
6. Müller F, Link I, Fuhr K, Utz KH (1995) Studies on adaptation to complete dentures. Part II: Oral stereognosis and tactile sensibility. J Oral Rehabil 22(10): 759-767.
7. Jacobs R, BouSerhal C, van Steenbergh D (1997) The stereognostic ability of natural dentitions versus implant-supported fixed prostheses or overdentures. Clin Oral Investig 1(2): 89-94.

8. Eitner S, Wichmann M, Schlegel A, Holst S (2007) Clinical study on the correlation between psychogenic dental prosthesis incompatibility, oral stereognosis, and the psychologic diagnostic tools SCL-90-R and CES-D. Int J Prosthodont 20(5): 538-545.

9. Litvak H, Silverman S I, Garfinkel L (1971) Oral stereognosis in dentulous and edentulous subject. J Prosthet Dent 25(3): 139-151.

10. Grosso JE, Catalanatto FA (1979) The effect of age and full palatal coverage on oral stereognostic ability. J Prosthet Dent 41(2): 215-219.

11. Kawagishi S, Kou F, Yoshino K, Tanaka T, Masumi S (2009) Decrease in stereognostic ability of the tongue with age. J Oral Rehabil 36(12): 872-879.

12. Kawagishi S, Tanaka T, Shimodozono M, Yoshino K (2013) Simplifying the assessment of stereognosticability of the tongue in elderly subjects using six selected test pieces. Aging Sci 1:3.

13. Mantechini G, Bassi F, Pera P, Preti G (1998) Oral stereognosis in edentulous subjects rehabilitated with complete removable dentures. J Oral Rehabil 25(3): 185-189.

14. Smith PW, McCord JF (2002) Oral stereognostic ability in edentulous and dentate individuals. Eur J Prosthodont Restor Dent 10(2): 53-56.

15. Kumamoto Y, Kaiba Y, Imamura S, Minakuchi S (2010) Influence of palatal coverage on oral function: Oral stereognostic ability and masticatory efficiency. J Prosthod Res 54(2): 92-96.

16. Premkumar S, Venkatesan SA, Rangachari S (2011) Altered oral sensory perception in tongue thrusters with an anterior open bite. Eur J Orthod 33(2): 139-142.

17. Grossman RC (1964) Methods for evaluation oral surface sensation. J Dental Res 43(2): 301.

18. Berry DC, Mahood M (1966) Oral stereognosis and oral ability in relation to prosthetic treatment Br Dental J 120(4): 179-185.

19. Hochberg I, Kabcenell J (1967) Oral stereognosis in normal and cleft palate individual. Cleft Palate J 4: 47-57.

20. Laine P, Siirilä HS (1971) Oral and manual stereognosis and two-point tactile discrimination of the tongue. ActaodontologiaScandinavica 29(2): 197-204.

21. Siirikka H, Laine P (1967) The relation of periodontal sensory appreciation to oral stereognosis and oralmotor ability. Suom Hammaslaak Toim 63: 207-211.

22. Kawagishi S, Tanaka T, Yoshino K, Shimodozono M (2014) Brain activity during stereognostic discrimination using the tongue measured by functional near-infrared spectroscopy. Aging Sci 2: 128.

23. Kappers AM (2011) Human perception of shape from touch. Philos Trans R Soc Lond B Biol Sci 366: 3106-3114.

24. Calhoun KH, Gibson B, Harty L, Minton J, Hokanson JA (1992) Age-related changes in oral sensation. Laryngoscope 102(2): 109-116.

25. Kawamura P, Wessberg GA (1990) Perioral somesthetic sensibility. J Oral Maxillofac Surg 48: 1181-1190.

26. Landt H, Fransson B (1975) Oral ability to recognize forms and oral muscular coordination ability in dentulous young and elderly adults. J Oral Rehabil 2(2): 125-138.

27. Pow EH, Leung KC, McMillan AS, Wong MC, Li LS, et al. (2001) Oral stereognosis in stroke and Parkinson's disease: a comparison of partially dentate and edentulous individuals. Clin Oral Investig 5(2): 112-117.

28. Leung KC, Pow EH, McMillan AS, Wong MC, Li LS, et al. (2002) Oral perception and oral motor ability in edentulous patients with stroke and Parkinson's disease. J Oral Rehabil 29(6): 497-503.