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The reliability and validity of descriptions of misarticulated sounds according to several articulatory features

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THE RELIABILITY AND VALIDITY OF DESCRIPTIONS OF MISARTICULATED SOUNDS ACCORDING TO SEVERAL ARTICULATORY FEATURES

by

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INTRODUCTION

Articulation can be assessed from three general viewpoints: physiological, acoustical, and perceptual. Clinically, articulatory assessment usually refers specifically to the perceptual system, where the evaluator determines the adequacy of the speaker's production of the phonemic code of the language by listening to a sample of the speaker's speech. This is a judgmental process engaged in by the evaluator (Noll, 1970). It depends on the listener's inferences, presumably drawn from the acoustic clues, concerning the placing and coordinating of the several structures responsible for the articulation of speech sounds in and around the vocal tract of the speaker.

The most frequently used types of articulatory classifying schemes are quite gross and give away a great deal of information. In many of the standardized tests, the evaluator is instructed to mark down whether the subject omitted, distorted, or substituted for the sound under test. Frequently, description of misarticulations is discouraged through the provision of symbols which simply indicate the occurrence of an omission or distortion (Arizona Articulation Proficiency Scale). The evaluator is not given any encouragement to spend time determining the nature of the distortion used, nor to delve more deeply into any elements of the target phone which may be present in the misarticulation. In addition, it is seldom that evaluators make distinctions between the allophones of English phonemes. For example, 'p' and 'p^h' are transcribed as /p/,

siderable variation between evaluators as to which allophones they will regard as correct in specific contexts; it is conceivable that one evaluator might judge a child's aspiration of the 'p' in the /sp/ phoneme cluster, as produced in [$sp^{h}un$] as incorrect while another evaluator might score it as correct.

Tests such as the Templin-Darley Tests of Articulation and the Arizona Articulation Proficiency Scale concentrate on sampling the articulation skill of an individual such that his skill may be compared to norms for his age group; the norms serve as a basis for the judgment concerning whether the subject is exhibiting significantly deviant articulation. Several studies have concentrated on establishing normative data for the developmental acquisition of the sounds of the language (Irwin, 1947, 1948; Templin, 1957; Wellman, 1931), but only relatively recently have studies been done on the nature of the speech-sound errors occurring in the speech of children. Some of the work in this area has been done by Snow who examined the sound errors of a large number of first-grade children (Snow, 1964). She found many instances where the sound substitutions of children closely corresponded to the listening errors made by adults listening to speech against a background of noise.

It is possible to consider speech sound as a specific bundle of features. A number of schemes have been devised which use sets of distinctive features to describe the bundle of events which occur in the production of a sound. This type of classification system promises a more detailed and comprehensive means of describing sound production, and as such has application in describing the fine elements of sound production for both the normal and the deviant speaker.

REVIEW OF THE LITERATURE

Distinctive Features

The early distinctive feature schemes had a supposedly perceptual base. Much of the work was based on visual acoustic displays of short utterances. Researchers such as Cooper (1952) analyzed speech production using a sound spectrograph and patterned playback. The analysis of the spectrographic material led to the use of such terms as "diffuse" and "compact", "grave" and "acute", etc. This terminology was utilized by Jakobson, Fant, and Halle (1952) in a scheme which was comprised of nine binary contrasts of a similar nature to the ones listed above; for example, "voiced" and "nonvoiced". It was felt by the authors that these contrasts were universal, and they were considered to describe perceptual linguistic reality with the greatest economy. These distinctive features should be imposed one upon the other at any particular instance in a speech sample, and the particular cluster of features present formed the phoneme bundle.

A different approach to describing the degrees of perceptual difference between phonemes was carried out by Miller and Nicely (1955). This system used only the contrasts of English and considered the features of voicing, nasality, affrication, duration, and place of articulation. Miller and Nicely concluded that "the perception of any one of these five features is relatively independent of the perception of the others".

In the 1960's the emphasis moved away from the use of spectrographic material as a means of analyzing speech sounds, and interest turned towards articulatory feature schemes. In 1962, Fant extended the system which he had helped to develop with Jakobson and Halle because he felt that, while it might have application for phonological theory, it was not precise enough to cope with the problems of speech-sound recognition. Fant proposed a system which was not dependent on the beginning and termination of phoneme boundaries. He divided the spectrum of the speech utterance into "sound segments" which can extend from one phoneme to another.

> ... When sound segments are decomposed into bundles of simultaneous sound features it is often seen that a single sound feature carrying a minimal distinction may extend over all sound segments of importance for a phoneme, including sound segments which essentially belong to adjacent phonemes.

This proposal was of great importance to the concept of coarticulation where some features of one phone may either precede or continue after the actual production of the phone, thereby having considerable influence over adjacent phones in the speech sequence.

This same principle was stressed by Peterson and Shoup (1966) in terms of the importance of secondary phonetic features. Peterson and Shoup devised a phonetic theory based on physiological parameters. In their discussion on secondary parameters, for example when discussing tongue tip placement, they comment that there are several different articulatory formations such as velarization or lip rounding which give an acoustic impression very similar to that of retroflection although physiologically the tongue tip is not retroflexed. Thus Peterson and Shoup imply that inferences drawn from acoustical data and concerning articulatory events may sometimes be erroneous or may have to choose among several articulatory events producing essentially equivalent acoustic outputs.

Such feature schemes as the ones cited above have been evolved to make fine descriptions of the "normal" sound system possible. Such schemes are, however, equally useful in describing the abnormal sound system. A step in this direction has been taken by Haas. He postulated that the correction of a child's articulation errors could best be achieved by investigating in detail how the phoneme system which the child has developed for his own use corresponds to the phoneme system of his native language as used by the adults in his environment. Haas studied the phonemic system of a child with deviant speech. He determined that the child was operating according to his own set of phonological rules, and as a result Haas recommended that the place to start in correcting the child's deviant speech would be with those features missing from the child's phonological system which could be acquired with the least difficulty (Haas, 1963).

Considering phonemes as bundles of features is stressed by Compton (1970). "One must regard sounds not as indivisible entities, but instead as being composed of intersecting subcomponents or attributes." In his paper Compton makes a detailed analysis of the deviant articulation of two children and says, "the errors characterizing articulatory disorders are generally not specific to single sounds but, rather, are a reflection of systematic patterns of errors encompassing entire classes of sounds possessing one or more features in common".

For several reasons, then, the use of distinctive features to describe children's phone errors would seem to promise advantages over traditional methods of describing faulty sound production: Firstly, more detail regarding the nature of the misarticulation is retained. Secondly, the relationships between sets of errors become discoverable and the child's phonological system can be inferred.

If the above techniques of sound-error judgments involve inferences, regarding articulatory events and derived from auditory cues, then the question may be asked if any method for more direct viewing of the articulatory events has been tried.

X-ray Studies

It may be very important for the clinician to know precisely how the child is manipulating his oral mechanism in order to produce the speech sounds which he is misarticulating. One method of determining what is happening inside the oral cavity is by means of lateral head x-rays. This approach has been used by a number of investigators.

Daniloff and Moll (1968) used high speed cinefluorographic films while investigating the extent of coarticulation of lip rounding in selected speech strings. In their study they found that for most utterances investigated, the lip rounding gesture associated with the vowel /u/ began during the approach to the closure phase of the first consonant in the sequence, extending over as many as four consonants preceding the vowel. Perkell (1969) did a cineradiographic study with reference to basic articulatory differences in the physiology of consonant and vowel production. X-rays have also been used in the investigation of esophageal speech patterns (Shipp, 1967) and of speech patterns before and after pharyngeal-flap operations (Subtelny, 1969). The use of x-rays as a means of visualizing the functioning of the speech mechanism has therefore found acceptance over a varied field of studies.

A survey of the literature reveals that analyzing speech samples by means of distinctive features will give much more information than can be gleaned from determining which target phonemes were misarticulated. The use of a distinctive feature analysis has relevance to the description of deviant speech as well as normal speech, and focuses attention on commonalities of articulation errors across phoneme boundaries; a most important step if the phonological system of the child is to be understood. The actual movement of the child's oral musculature inside the oral cavity can be visualized during speech by means of lateral head x-rays.

Not covered by the existing research, however, are the following questions: Can judges using a phonetic feature scheme do so with acceptable reliability? Can judges using a phonetic feature scheme do so with acceptable validity?

Statement of the Problem

If an articulatory distinctive feature scheme is practically useful, then its reliability, and secondly its validity, must be demonstrated. Information is needed concerning the reliability and validity of the judgments of trained listeners using a distinctive feature scheme to record the errors of defective speakers. It is tacitly accepted that persons using an articulatory feature scheme and a "good" ear (after some training in its use) should be able to make a fairly accurate analysis of the way in which sounds are produced without regard to whether such sounds are correctly or incorrectly produced. However, such a scheme may necessitate that the evaluator rely on feedback from his own "normal" mechanism to make the analysis of events taking place inside the subject's mouth. One means of obtaining a view "inside" the speaker's mouth while he is articulating is to use x-ray moving pictures of his oral region. The lateral head x-ray views provide information about the activity of the speech structures inside the mouth of the person exhibiting deviant articulation.

Distinctive features promise much, but their reliability and validity is unknown. The present study was designed to investigate these unanswered questions.

This study investigated the use of an articulatory distinctive feature scheme in describing some deviantly produced phones. A group of sixteen judges was asked to make scaled judgments of eight preselected phones using information, both auditory and visual, from two videotapes-- one giving a full face view of the speakers, and the other showing x-ray moving pictures of the speakers' oral regions as they produced the misarticulated phones in words.

This investigation attempted to answer the following questions:

1. What is the intra- and interjudge reliability on selected aspects of a distinctive feature scheme when using the auditory and visual information from:

    a) a full face videotape
    b) a lateral head view radiographic videotape?

2. Assuming that the lateral radiographic videotape reveals the "true" state of the articulating structures during the production of selected phones, how valid are the feature judgments made from the full face videotape?

CHAPTER II

PROCEDURE

Sixteen graduate students of speech pathology and audiology evaluated, as to selected manner and spatial articulatory features, eight deviantly articulated phones presented on two videotapes. The same eight phones were pictured on each of the two videotapes, one a full face view of the subject, and one a lateral radiographic view of the oral region of the subject. The 16 judges were randomly assigned to two subgroups of eight judges each, and each subgroup performed the evaluation task twice. Subgroup A saw the x-ray tape first and subgroup B saw the full face tape first. A week later, subgroup A saw the full face tape first and subgroup B saw the x-ray tape first. Prior to the first evaluating session, each subgroup of judges received an hour's training in using the articulatory distinctive features and in recognizing the relevant oral landmarks on both the full face and the x-ray videotapes. The judges then viewed the experimental tapes and described the misarticulated sounds using the articulatory feature scheme.

STIMULUS MATERIAL

The stimulus material for all the evaluating sessions consisted of two prerecorded videotapes of eight preselected phones produced within words by five children. Videotape "A" was a full face view of the child producing the word, and videotape "B" was a lateral x-ray of the child's oral region during production of the same word. The two videotapes were made simultaneously. The eight experimental sample words were separated one from another on the videotape by 30-second intervals to allow time for the judges to evaluate each feature. It was found during a pilot study that an average of seven presentations at 20-second intervals were needed to make possible thoughtful judgments concerning each articulatory feature. The experimental tapes were therefore constructed so that each word was repeated 10 times at 30-second intervals to allow an extra margin of safety. During each evaluating session, each word was presented to the judges 20 times, 10 during the full face presentation and 10 times during the x-ray presentation, making a total of 40 presentations of each word over the two evaluating sessions. The presentation of the videotapes was arranged for the first evaluating session so that subgroup A of judges viewed the x-ray material first and then the full face material, while subgroup B viewed the full face first and then the x-ray; during the second evaluating session these orders were reversed.

SPEAKERS SELECTED FOR STUDY

The children who were videotaped to provide the stimulus material were selected from the large clinical population of the department of Speech Pathology and Audiology at the Glenrose Provincial General Hospital, which is a rehabilitation hospital in Edmonton, Alberta. The criteria for selection of the children were as follows:

1. The children must have functional articulation problems with no indications of hearing loss, dysarthria, cleft palate, etc.
2. They must have been diagnosed as producing subsitutions for the sounds selected for this study.
3. They must have the majority of the growth in their oral region completed. (Consequently, the age of the children ranged between five years ten months, and nine years four months.)
4. The children must have no structural abnormality in the oral region.
5. The children must not have been exposed to any large doses of radiation during their lives, nor should they have received any radiation within the past six months.
6. The children must be relatively cooperative and able to keep their heads still during the production of the words. (This latter requirement was necessary if clear x-rays of the oral region were to be obtained.)

A list of children who met the criteria was compiled and the children were then screened by the experimenter and a list of words containing the appropriate phones was devised for each child. A training session in which each child was conditioned to produce the appropriate word in response to a large picture was carried out immediately prior to the recording session.

PHYSICAL SETUP

The videotape recordings were made in the Radiography Department of the Glenrose Hospital, with the assistance of a radiographer and a radiologist, both of whom had five years' experience in the use of videotaped x-ray studies of the posterior oral region for the determination of velopharyngeal sufficiency.

The recordings were made with the subject standing beside the fluoroscope, the head being held steady by a modified head clamp, and the x-ray images of the oral region being fed directly into a videotape recorder (Figure 1). At the same time a second camera recorded a full face view of the subject which was fed into a second videotape recorder. The auditory signal during production of the words was recorded on both videotapes. The room lighting was kept as bright as possible during the recording in order to obtain a clear picture of the subject's face. A good quality microphone was positioned at an optimum distance from each subject in order to receive a clear auditory signal on the tape recording. It was not possible to eliminate fluoroscope machine noise entirely, but noise was kept as low as possible so that it would not mask the auditory signal on the tape recording. This was achieved by using a directional microphone to pick up the subjects' voices.

A barium compound was painted along the midline of each subject's tongue from the anterior tip as far back as possible without causing discomfort, just prior to the recording. It was found during a pilot study that this procedure greatly improved the differentiation obtained on the videotaped x-rays.

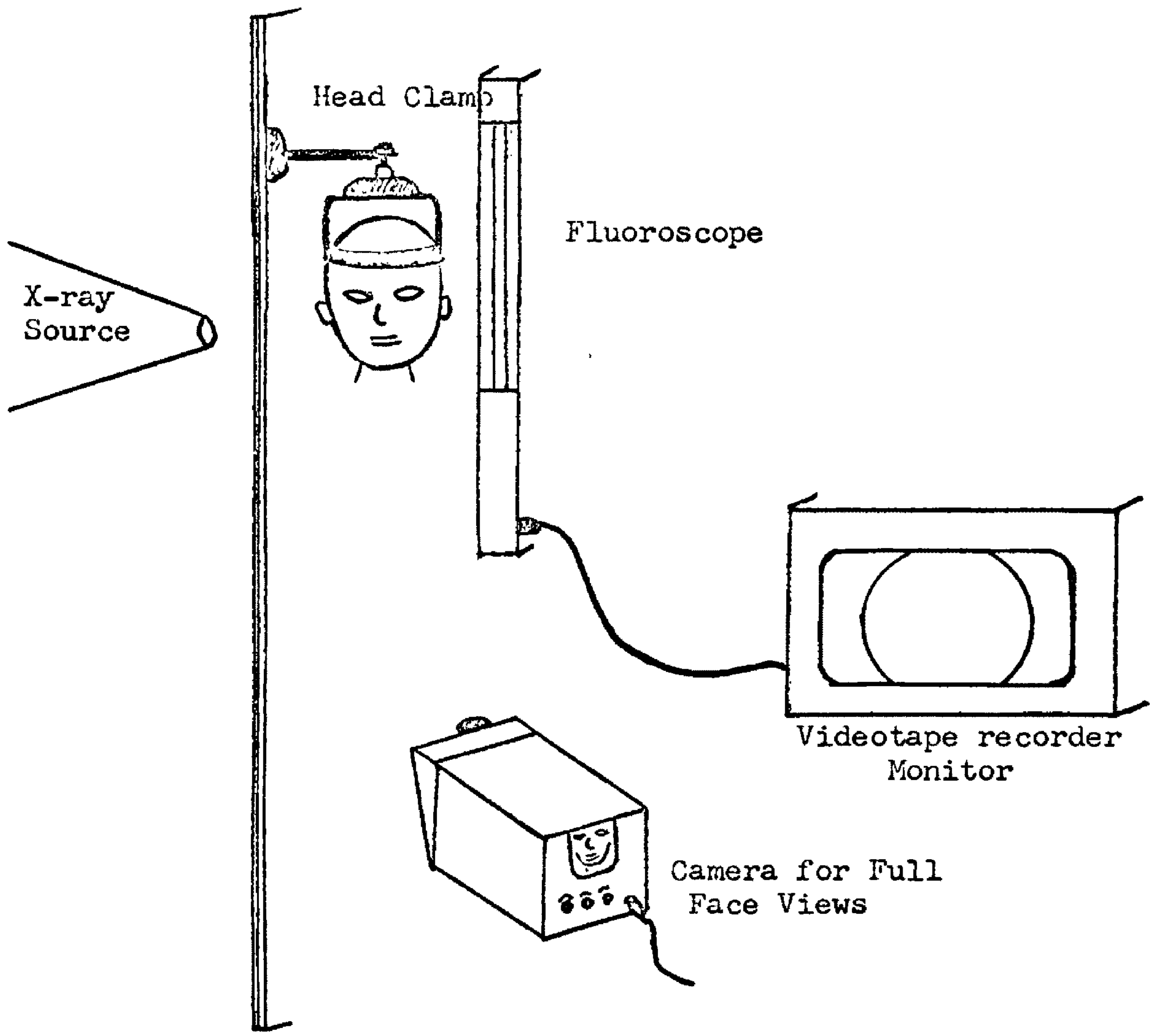

Figure 1. Physical Setup Showing Position of Speaker, the Head Clamp, the Fluoroscope, the X-ray Source, the Monitor and the Camera for the Videotape Recorders.

PERSONNEL AND SAFETY CONSIDERATIONS

In addition to the subjects, a radiologist, a radiographer, an assistant, and the experimenter were present during the recording session. All personnel present wore lead aprons as a safety precaution.

Radiation hazard measurements were taken prior to the recording session using an EIL Model 37c x-ray Dosimeter and a 350cc chamber. The accuracy with this equipment is expected to be generally better than ± 10%. The control setting was 60KV peak and 3.4 mA maximum with an adult phantom in place for the lateral pharynx. The entrance dose rate with the phantom in place and including backscatter was found to be 440 mR/minute. The exist dose rate with the phantom in place and including scatter was found to be 6 mR/minute. The scattered radiation at the front side of the table at a distance of 40 inches was found to be 0.05 mR/minute and 4 mR/hour if the table barrier was not in place. The National Council on Radiation Protection report number 33, "Medical X-ray and Gamma-ray Protection for Energies up to 10 MeV", states on page 10 that "with modern equipment, most fluoroscopy can be carried out with exposure rates of less than 5 R/minute". The 0.440 R/minute levels found prior to the recording session were well below this level and those levels indicated on page 42, Appendix B, of the NCRP report. The levels quoted in the report are from an United States government publication.

An exposure of 50 R over a very short period will produce minute changes in the lymphatic tissue of the body, and an intense exposure of 100 R is needed before any genetic changes can be detected. In order to reduce the possibility of cumulative effects of radiation, one of the criteria for selection was that the child should not have been exposed to radiation within the last six months. In actual fact, only one child had received x-rays prior to this study-- a dental x-ray 18 months previously. It was felt by the radiographic consultant called in to make the readings of the radiation hazard that the procedures carried out were well within limits usually accepted as conservative. The length of time each subject was exposed to radiation during the recording session ranged from 10 seconds to 68 seconds, with a median exposure of 32 seconds. The range of cumulative radiation exposure was from 0.073 R/minute to 0.500 R/minute. Therefore, the highest level of cumulative radiation was one hundredth of the exposure necessary to cause minute changes in the lymphatic tissue of the body.

PHONES SELECTED FOR STUDY

In order to sample across the broad range of the English phonological system, the following phones were selected for recording: θ, t, s, l, and k. The particular phones selected were such that the x-ray picture would be able to provide valuable information about the actual place of articulation and other relevant features. The words selected to contain the phones were: thumb, turtle, seal, glass, house, moose, lamb, and cake. Four different substitutions occurred for the four /s/ phones included in the study.

ARTICULATORY PHONETIC FEATURES USED

Those features which could be described from the x-ray of the oral region were included for the purpose of this study. The features were: time, transition speed, place of articulation, tongue part, tongue shape, and tongue elevation. The features are shown on a sample judgment sheet, Figure 2. Each feature was rated on a seven-point scale with 4 representing normal, 1 representing "too little" or "too far forward", 7 representing "too much" or "too far back", and the other scale values provided graduated points within the two extremes.

RELAIBILITY AND VALIDITY

It was decided before the experimental procedure was carried out that a high reliability would be defined as a discrepancy of one scale unit or less when repeated judgments of the same sound were compared. Reasonable reliability was defined as a judgmental discrepancy of 1.9 scale points or less. Judgmental discrepancies of greater than 1.9 scale points would be regarded as demonstrating poor reliability. These definitions were based on a consideration of the fact that a deviation 2.0 scale points or over would involve a difference in placement as discrepant as "a little behind the usual position on the hard palate" to "on the anterior soft palate". A more detailed description of the appropriate scale ratings to the various placement areas within the oral region and the appropriate ratings for the other features is given in the script of the training session (Appendix A).

Judge's name ______________________ Date ______________

Word ______________ Sound ____________ _____X-ray ____ Full face

	1	2	3	4	5	6	7
<u>Time</u>							
onset			✓				
nucleus					✓		
offset				✓			
<u>Transition speed</u>							
consonant to vowel							
vowel to consonant			✓				
glide							
<u>Place</u>							
bilabial							
labiodental							
interdental							
dental				✓			
alveolar							
palatal							
velar							
pharyngeal							
glottal							
<u>Tongue part</u>							
tip			✓				
blade							
dorsum							
<u>Tongue shape</u>							
forward				✓			
retroflex							
<u>Tongue elevation</u>			✓				

<u>Rating Scale</u>

"1" -- too little or too far forward
"4" -- normal
"7" -- too much or too far back

Figure 2. Judges' Articulatory Feature Rating Form Showing Possible Sample Judgments

TRAINING SESSION

Prior to evaluating the experimental videotapes, the judges were given a training session. The training session was an hour long. During this time the principles of articulatory distinctive feature schemes were discussed. The judges were then given some training in recognizing and evaluating the actual distinctive features used in this study. Each feature was discussed, and examples given of different aspects of each feature in sample phones. The judges were given the opportunity to practice evaluating groups of features and to discuss their evaluations. They were also trained to recognize the anatomical features on an x-ray of the oral region and were given similar practice in scaling and evaluating the phonetic features in this medium. The judges were then asked to evaluate the experimental videotapes in the same manner. (Appendix A presents the scripts of the training session.)

TRANSCRIPTION OF JUDGMENTS

The judgements obtained from each graduate student were in the form of a set of psychological scale values ranging from 1 to 7 for each particular articulatory feature. The judgments concerning many features are logically inter-related; for example, judgments concerning place of articulation will usually identify one single area of the mouth to the exclusion of all others. Thus if an alveolar place is identified, dental, palatal, etc. judgments are excluded. Such judgments tend almost always to be mutually exclusive therefore. Further, the nine place features identified parts along a physical continuum (the mouth from front to back). For these sets of reasons, the 7-point scales for each of the 9 place features were numbered consecutively from 1 to 63. For similar reasons the transition speed, tongue part, and tongue shape scales were each also numbered consecutively (Figure 3). The rating scale may have caused some inconsistencies in the difficulty of judging the place of production of some phones. The judges were required to break up the interdental, dental, and alveolar areas into seven points each, which required a much finer discrimination than the similar judgements concerning the palatal and velar regions (which later covered a much larger area by any physical measure).

SUMMARY

Eight phones were presented to 16 judges who made judgmental ratings of them using some articulatory phonetic features in the description. The judges viewed the phones on two occasions and made their judgments from both a full face videotape and an x-ray videotape of the subjects' oral regions during production of the phones.

Judge's name ______________________________ Date _________________

Word ________________ Sound ____________ _____X-ray _____ Full face

	1	2	3	4	5	6	7
Time							
onset	1	2	3	4	5	6	7
nucleus	1	2	3	4	5	6	7
offset	1	2	3	4	5	6	7
Transition speed							
consonant to vowel	1	2	3	4	5	6	7
vowel to consonant	8	9	10	11	12	13	14
glide	15	16	17	18	19	20	21
Place							
bilabial	1	2	3	4	5	6	7
labiodental	8	9	10	11	12	13	14
interdental	15	16	17	18	19	20	21
dental	22	23	24	25	26	27	28
alveolar	29	30	31	32	33	34	35
palatal	36	37	38	39	40	41	42
velar	43	44	45	46	47	48	49
pharyngeal	50	51	52	53	54	55	56
glottal	57	58	59	60	61	62	63
Tongue part							
tip	1	2	3	4	5	6	7
blade	8	9	10	11	12	13	14
dorsum	15	16	17	18	19	20	21
Tongue shape							
forward	1	2	3	4	5	6	7
retroflex	8	9	10	11	12	13	14
Tongue elevation	1	2	3	4	5	6	7

Rating Scale

"1" -- too little or too far forward
"4" -- normal
"7" -- too much or too far back

Figure 3. Judges' Articulatory Feature Rating Form Showing the Scale Values Assigned to Each Judgment Possibility.

CHAPTER 3

RESULTS AND DISCUSSION

The data of this study were scale values for each of eight articulatory features used in descriptions of eight misarticulated speech sounds. These data were analyzed to evaluate two dimensions of the data, their reliability and their validity.

Two kinds of reliability were distinguished and evaluated, intrajudge reliability and interjudge reliability.

Concerning validity, it was decided, a priori, that the most revealing views of each child's sound-producing efforts were his x-ray views taken while he was attempting the phone in question. The scale values produced by the judges responding to the x-ray views were, therefore, taken as the best representation of "reality", i.e. where the tongue really was positioned during the attempt at a given phone, etc. The mean of such scale values for each feature and each phone and over responses to both x-ray views were considered to represent the real state of affairs respecting any feature, and were the standard for comparison in the validity study.

Each of the judgements assigned to each feature on each phone by each exposure mode took the form of a scale value (as described in the Procedure chapter). This system allowed a discrete value to be assigned to the rating scale for each feature, and these discrete values were used in the calculations. Where no response was made by a judge for a particular feature, such judgments were not taken into account in the

RELIABILITY

From the raw data a table of discrepancies for each phone and feature was devised by subtracting each individual judge's rating on the second session x-ray from his judgment on the first session x-ray, and subtracting each judge's rating on the second session full face from his judgment rating on the first session full face (Appendix C). The table of discrepancies was then examined for significant deviations between judges and between x-ray and full face judgments. It was noted that while certain features showed wide discrepancies for certain elements (e.g. the place feature for the initial phone in "lamb" showed an x-ray interjudge mean discrepancy of 7.67 scale points whereas the full face interjudge mean discrepancy was 17.47 scale points) the majority of the full face and x-ray discrepancies were comparable (Figure 4 comparing the x-ray and full face discrepancies for the phone in "turtle"). The discrepancy of the x-ray judgments and the full face judgments rarely varied more than two scale points when the x-ray and full face discrepancy means for each feature within each phone were compared. The judgments therefore showed equivalent variations in reliability for the x-ray and full face modes. In view of their essentially equivalent reliability, and because full face is the usual mode of perceiving data about articulation, further analyses of the reliability of judgments were confined to the data from the full face mode.

The judgments were analyzed for reliability in two ways: by articulatory feature and by phone. The discrepancy scores for each judge were first summed over all phones, thereby yielding an estimate of

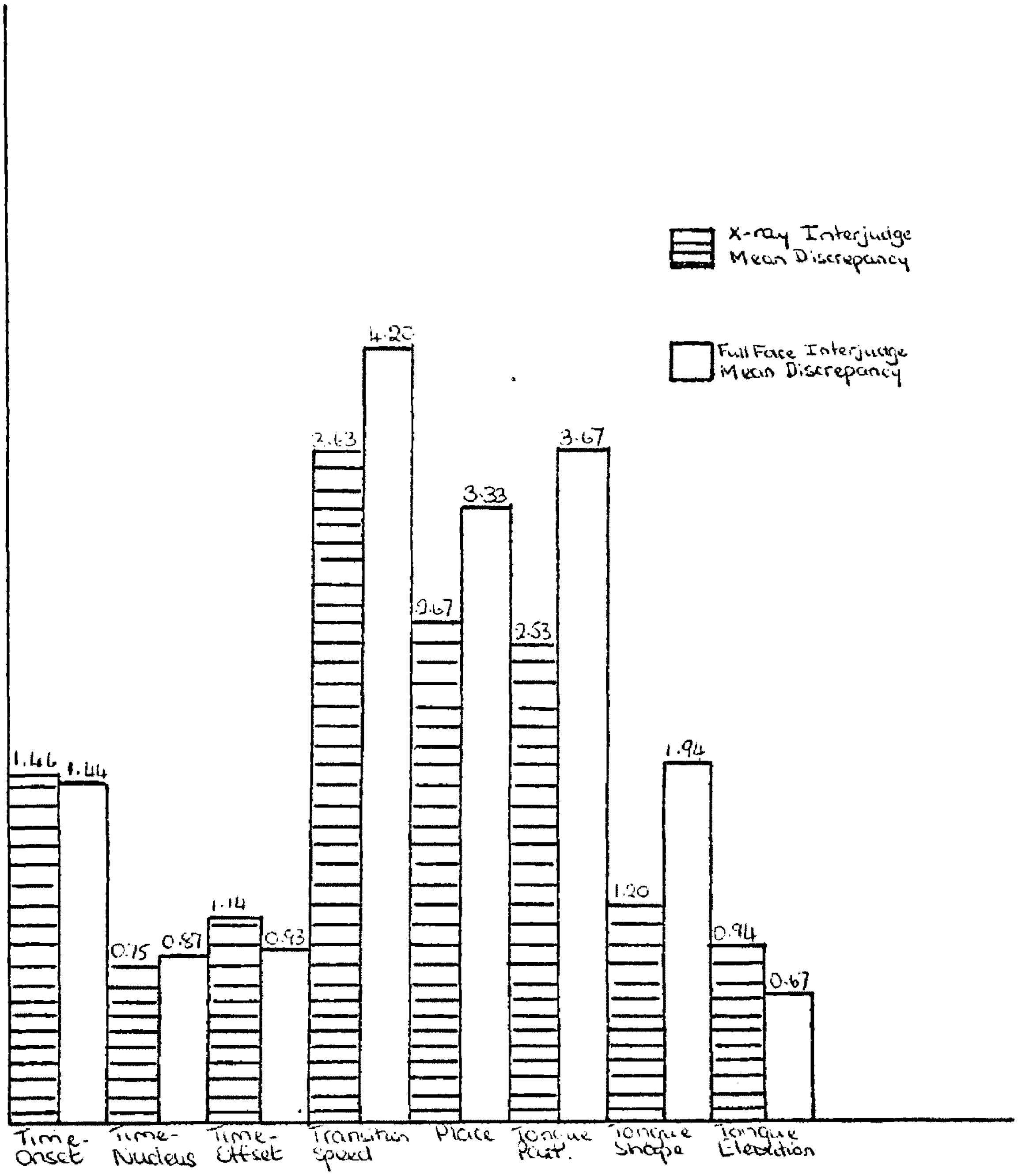

Figure 4. Interjudge Mean Discrepancies Comparing the Judgments for the X-ray Mode and the Judgments for the Full Face Mode for the Phone in "Turtle."

reliability as related to judgments of a child's skill in executing a given articulatory feature. Secondly, the discrepancy scores for each judge were summed over all features, thereby yielding an estimate of reliability as related to a child's attempts at a single phone.

Feature

The mean discrepancy scores derived from this analysis (Table 1) showed that the reliability as related to some features was in excess of the a priori limits set for adequate reliability, i.e. 1.9 scale points or less. As was previously explained, it was felt that to accept a discrepancy score of greater than two scale points could mean that in certain instances the judge was unable to discriminate between two distinctly separate anatomical areas. However, some feature judgments fell well within the range of acceptability (Figure 5). In particular the following features showed the highest reliability: time, tongue shape, and tongue elevation.

Time-onset feature. Showed a range of intrajudge mean discrepancy scores from 0.33 to 2.13 scale units with an interjudge mean discrepancy score of 1.16 scale units. This finding would suggest that generally judges were able to determine if an element of the feature bundle occurred slightly before or after the other elements of the feature bundle, and that judges were able to make reliable scale ratings on the element concerned.

Time-nucleus feature. Showed a range of intrajudge mean discrepancy scores from 0.13 to 1.88 scale units with an interjudge mean discrepancy

Table I. Reliability According to Feature.
Means of Scale Value Discrepancies for Each Judge Over All Phones.

	Time-Onset	Time-Nucleus	Time-Offset	Transition Speed	Place	Tongue Part	Tongue Shape	Tongue Elevation
A	1.00	0.25	0.80	3.75	6.00	1.63	0.86	0.71
B	1.57	1.67	2.33	3.88	6.25	4.17	2.00	2.67
C	1.38	0.71	0.75	2.50	2.88	2.00	0.88	1.38
D	1.00	1.63	1.00	3.14	6.38	4.17	2.00	1.38
E	1.00	1.00	0.50	2.75	10.00	1.00	2.13	1.13
F	0.88	1.43	1.25	3.50	14.14	5.14	1.63	1.00
G	0.33	1.67	2.50	2.38	4.63	3.33	0.71	0.43
H	1.43	1.25	1.13	3.50	3.83	3.57	2.17	2.00
J	1.13	1.88	1.88	3.88	7.88	2.00	0.75	1.63
K	0.50	0.13	0.13	1.75	2.13	2.33	1.00	0.57
L	2.13	0.88	0.63	2.25	4.75	2.83	1.00	1.25
M	1.00	0.00	0.43	4.75	6.13	1.29	2.20	0.80
N	1.88	1.13	1.75	2.25	8.75	3.86	1.86	1.14
O	1.63	0.38	1.25	1.75	8.75	2.71	1.33	1.33
P	0.63	0.71	1.13	2.13	4.00	4.13	1.25	0.88
Q	1.13	0.63	0.75	0.88	6.38	1.00	2.57	0.00
[illegible]	1.16	0.97	1.14	2.82	5.99	3.08	1.52	1.14

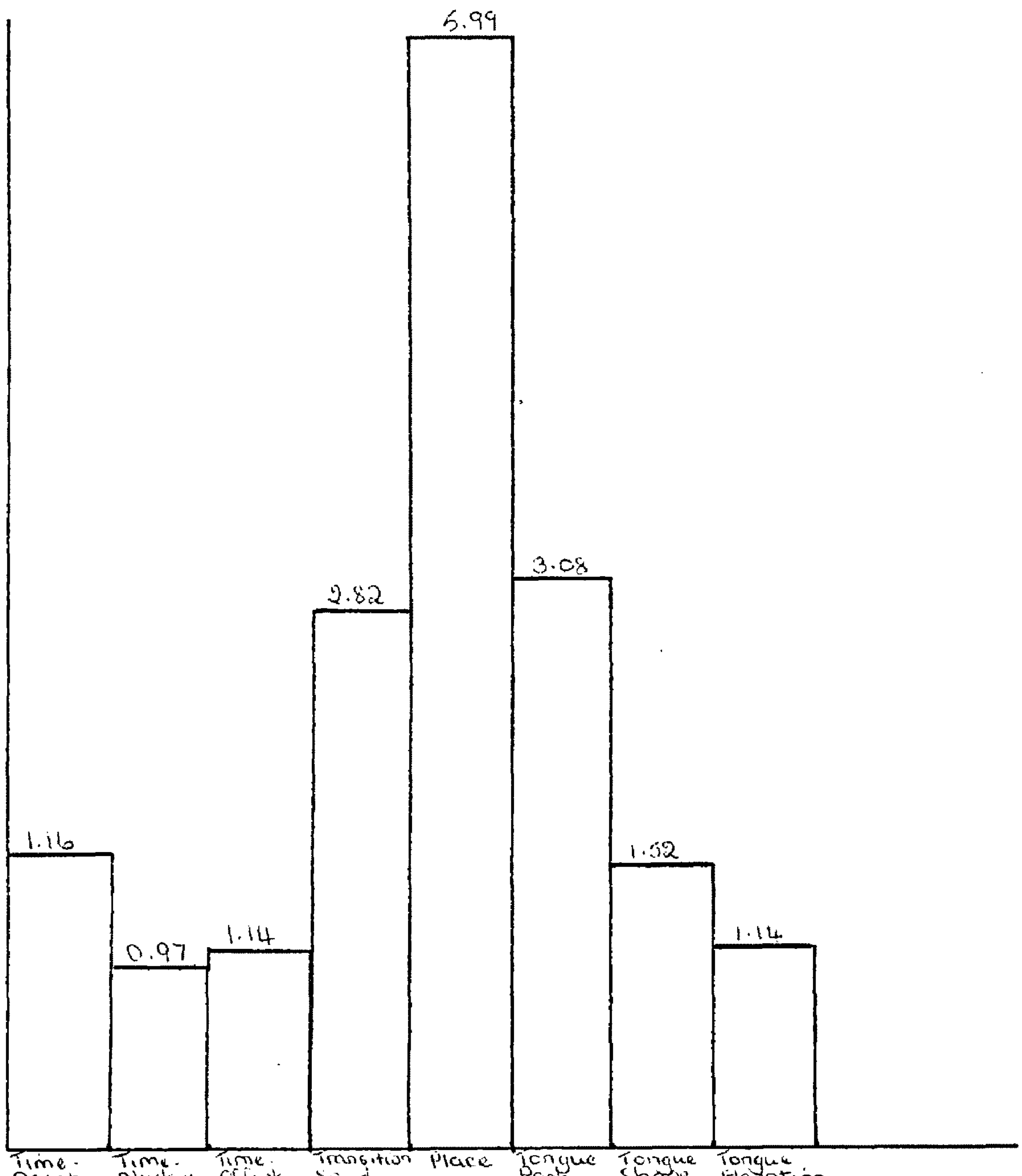

Figure 5. Reliability According to Feature. Means of Scale Value Discrepancies for Each Judge Over All Phones.

score of 0.97 scale points. This finding suggests that generally the judges could determine any abnormalities in the nucleus or central portion of a phone (the feature package). The judges could apparently make reliable judgments about elements of the central nucleus portion of the feature bundle which were adequately or inadequately maintained.

Time-offset feature. Showed a range of intrajudge mean discrepancy scores from 0.13 to 2.33 scale points with an interjudge mean discrepancy score of 1.14 scale units. This finding suggests that judges could reliably determine if an element of the feature bundle was abnormal in either finishing too quickly or being extended too long.

Tongue-shape feature. Showed a range of intrajudge mean discrepancy scores from 0.71 to 2.57 scale points with an interjudge mean score of 1.52 scale points. This finding would suggest that the judges could reliably determine whether or not the tongue was retroflexed and assign a scale value to the position utilized in the production of the sound.

Tongue-elevation feature. Showed a range of intrajudge mean discrepancy scores from 0.00 to 2.67 scale points with an interjudge mean discrepancy score of 1.14 scale units. This finding would suggest that the judges could reliably assign a scale value to the height of the tongue during the utterance of the sound under consideration.

Place, tongue-part and transition speed. Some of the other features showed a wider range of discrepancies, particularly the place feature. In this instance there was a range of intrajudge mean discrepancies from 1.83

to 14.14 scale points with an interjudge mean discrepancy of 5.99 scale units. It was felt that these large deviations could probably be accounted for as a function of the training session given to the judges. In particular it was felt that the judges required more training in identifying and discriminating primary and secondary articulation. For example, in the word "thumb", which could have been transcribed as /wʌm/ from the videotape, some judges described only the lip position for the /w/ whereas some other judges described only the tongue position for the /w/; this resulted in a large number of scale points of discrepancy between judgments (e.g. the judgments made by judges D and J for the word "thumb" [Appendix B, page 62]). These errors in place judgments also had an effect on the tongue part judgments since those judges who described the lip position for the /w/ would therefore decline to make a judgment about which part of the tongue was used for that sound. The feature of transition speed fell just outside the range of acceptability, having an interjudge mean discrepancy score of 2.82 scale points. Examination of the transition speed judgments revealed a scattering of judgments of vowel-consonant transitions concerning such phones as the /s/ in seal. There seemed, then, some confusion among the judges as to the nature of transitions.

Phone

Scale score discrepancies analyzed according to phone are presented in Table 2. While four of the interjudge mean discrepancy scores showed scale point discrepancies greater than 1.9 scale units, it seemed that the type of sound substituted for the phone under

ɪg on the mean discrepancy of the scale point

Table 2. Reliability According to Phone.
Means of Scale Value Discrepancies for Each Judge Over All Features.

	Cake	Lamb	Turtle	Thumb	House	Seal	Glass	Moose
A	0.71	6.33	0.75	1.29	0.57	2.29	1.75	2.75
B	2.00	4.75	3.29	1.67	4.00	5.43	1.83	1.80
C	0.88	2.75	1.50	1.67	1.13	2.25	1.00	1.14
D	0.83	8.00	1.25	3.17	1.33	2.29	3.29	1.29
E	1.13	1.13	2.63	1.28	8.14	1.13	2.38	2.38
F	4.57	5.63	1.63	6.00	2.75	2.88	4.13	1.57
G	2.14	2.17	1.43	2.50	1.17	2.17	2.38	3.00
H	1.86	3.71	2.14	1.00	1.17	2.29	1.13	4.63
J	1.50	2.57	3.75	1.67	1.86	0.88	1.50	1.25
K	0.86	4.57	2.25	0.25	1.14	0.63	3.38	1.38
L	0.86	3.38	1.63	0.57	0.75	2.63	1.38	1.00
M	1.50	5.63	2.25	3.20	0.40	0.63	0.60	1.13
N	1.13	5.57	3.75	1.00	0.50	2.88	3.75	1.50
O	2.38	5.86	1.75	0.57	1.50	2.88	2.25	2.00
P	2.38	2.00	2.57	0.67	1.86	1.38	2.38	0.88
Q	1.00	8.80	1.00	0.00	0.50	1.71	2.57	1.57
[illegible]	1.68	4.55	2.10	1.66	1.80	2.15	2.23	1.82

judgment made (Figure 6). For example, with a phone which obviously had a single place of articulation such as the /θ/ in /muθ/ ("moose"), the interjudge mean discrepancy score was 1.82 scale units; whereas with a phone which had both a primary and secondary place of articulation such as the /w/ in /wɑm/ ("lamb") the interjudge mean discrepancy score was higher, being 4.55 scale units. An interesting example of judges using primary articulation descriptions on one occasion and secondary articulation descriptions on another occasion can be seen in the judgment of judges A and B describing the phone in "thumb" (Appendix B, page 62). From examination of the data, it seems that some indivudal judges vacillated between judging the primary and secondary articulation, whereas other judges were consistent about what they described. As mentioned previously, such findings reveal the need for training judges to use care in describing both primary and secondary places of articulation.

The phones which showed the greatest reliability were "c̲ake", "t̲h̲umb", "h̲ouse", and "m̲oose", with interjudge mean discrepancy scores of 1.68, 1.66, 1.80 and 1.82 scale points respectively. It is interesting to note that the highest and lowest interjudge mean discrepancy scores were associated with essentially the same phone. For both "t̲h̲umb" and "l̲amb" the speakers substituted what was essentially a /w/. In the description of the sound in "t̲h̲umb" both judge B and judge G declined to make estimates for some of the features, having 5 and 6 no-responses respectively. Since a significant number of no-responses was not evident in the judgments of the phone in "l̲amb", this contributed to the higher discrepancy score for that phone, i.e.

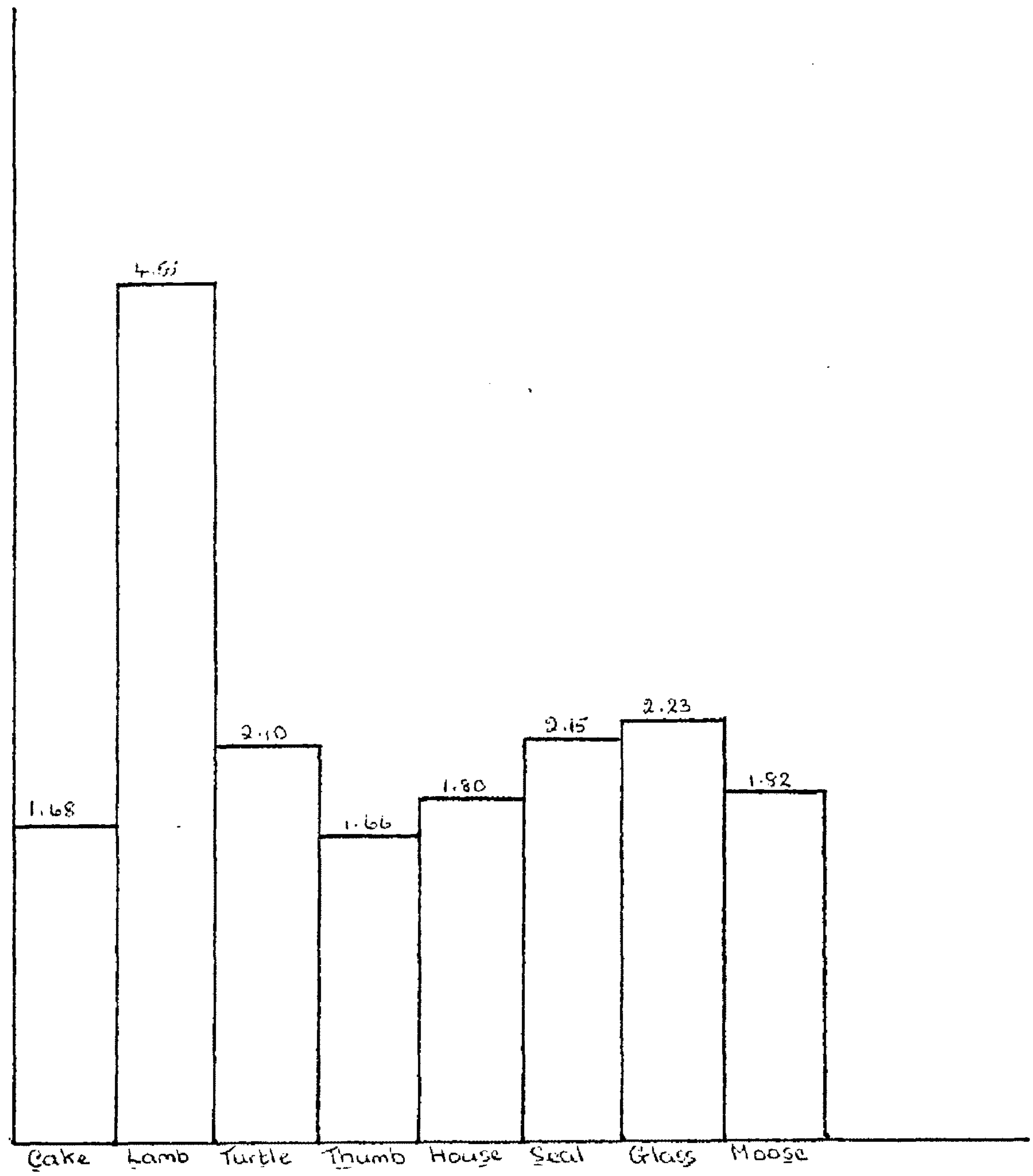

Figure 6. Reliability According to Phone. Means of Scale Value Discrepancies for Each Judge Over All Features.

for the judgments related to "lamb" the judges made 243 attempts to scale the features perceived, while in the judgments related to "thumb" the judges made only 226 attempts to scale the features perceived, thereby reducing the possibility of a discrepancy between scores. It is not altogether clear why the judges attempted description of the phone in "l̲amb" but tended to refuse to consider the status of similar features as manifested in the phone in "t̲h̲umb".

VALIDITY

In order to analyze the results for validity, each of the individual full face judgments was compared to the mean of the x-ray judgments. As was previously discussed, it was felt that the average of the interjudge means for the two x-ray sessions would provide the best estimate of the actual activity inside the speaker's mouth. A table of discrepancies of individual judgments from the x-ray mean was derived (Appendix D). Intra- and interjudge means were computed from these discrepancy scores. Three sets of tables presenting the discrepancy scores were derived as related to feature, phone, and order of presentation (Tables 3, 4 and 5).

Feature

The mean discrepancy scores derived from the analysis according to feature showed the same pattern of results as for the corresponding reliability table (Figure 7). Examination of the raw data suggested a possible explanation for the low means in the time judgments, namely that there was a preponderance of ratings at the "normal" part of the scale, and the mean judgments center around a rating of "4". The

onderance are open to conjecture, but it may have

Table 3. Validity According to Feature.
Means of Scale Value Discrepancies for Each Judge Over All Phones and Order of Presentation of the Experimental Tapes.

	Time-Onset	Time-Nucleus	Time-Offset	Transition Speed	Place	Tongue Part	Tongue Shape	Tongue Elevation
A	1.20	1.42	1.18	3.70	8.16	3.29	0.87	1.36
B	2.12	1.77	1.58	3.71	9.72	4.52	1.61	1.90
C	1.06	0.69	0.82	2.38	9.04	3.88	1.00	1.03
D	1.58	1.42	0.95	2.79	8.34	3.68	1.95	1.92
E	1.54	1.14	1.24	1.90	10.07	4.99	1.48	1.26
F	1.03	1.04	1.00	3.58	13.77	5.71	2.07	1.60
G	1.02	1.19	1.71	3.26	7.65	4.70	0.67	0.92
H	1.67	1.16	1.43	3.87	8.99	3.25	1.70	1.54
J	0.90	1.09	1.03	3.32	9.41	3.79	0.67	1.44
K	0.61	0.44	0.61	1.80	11.32	4.06	2.17	1.23
L	1.36	0.62	0.88	3.52	8.64	3.63	1.20	1.10
M	0.67	0.33	0.34	2.62	8.18	2.45	0.70	0.96
N	1.68	1.13	1.17	1.41	9.18	4.26	1.61	1.19
O	0.81	0.38	1.08	1.57	8.37	3.13	1.21	1.48
P	1.02	0.73	0.91	1.54	7.97	3.46	1.91	0.93
Q	1.03	0.85	0.65	1.37	8.01	2.95	2.90	0.90
[illegible]	1.21	0.96	1.04	2.65	9.18	3.86	1.48	1.30

Table 4. Validity According to Phone.
Means of Scale Value Discrepancies for Each Judge Over All Features and Order of Presentation of the Experimental Tapes.

	Cake	Lamb	Turtle	Thumb	House	Seal	Glass	Moose
A	1.27	5.16	1.69	3.74	5.77	2.23	2.39	1.76
B	2.34	5.38	2.14	3.69	4.99	2.98	2.95	4.07
C	1.88	5.14	1.86	1.50	4.30	1.80	1.74	1.84
D	2.40	4.11	2.30	3.55	5.34	1.85	2.07	2.09
E	1.25	5.75	2.59	2.89	4.99	1.50	2.25	2.50
F	2.74	3.37	3.26	6.04	6.43	1.88	3.33	2.34
G	1.99	4.95	2.23	2.65	5.03	1.90	1.94	2.07
H	1.58	5.44	1.90	4.12	5.97	2.21	1.58	2.21
J	1.26	2.16	2.46	5.55	5.42	1.03	1.39	1.82
K	1.65	3.08	1.92	2.20	5.37	1.75	2.49	1.46
L	1.37	5.41	1.61	3.77	4.39	1.48	2.05	1.00
M	1.55	3.39	1.26	2.92	5.03	0.66	1.64	1.73
N	0.83	3.67	2.18	2.61	5.44	1.78	4.12	1.40
O	2.23	3.08	1.70	2.22	4.82	1.85	1.86	1.23
P	1.59	2.31	1.78	1.88	4.95	1.18	1.73	2.29
Q	0.93	3.82	2.90	1.71	4.63	1.78	2.15	1.36
[illegible]	1.68	4.14	2.11	3.19	5.17	1.74	2.23	1.95

Table 5. Validity According to Order. Means of Scale Value Discrepancies for Each Judge Over All Phones and All Features.

	1st session full face	2nd session full face
A	2.61	2.92
B	3.73	3.32
C	2.64	2.20
D	2.89	2.90
E	3.03	2.86
F	3.51	3.80
G	3.28	2.43
H	3.01	3.00
J	2.71	2.35
K	2.33	2.52
L	2.48	2.69
M	1.79	2.35
N	2.64	2.66
O	2.47	2.03
P	2.25	2.15
Q	2.44	2.26
[illegible]	2.74	2.65

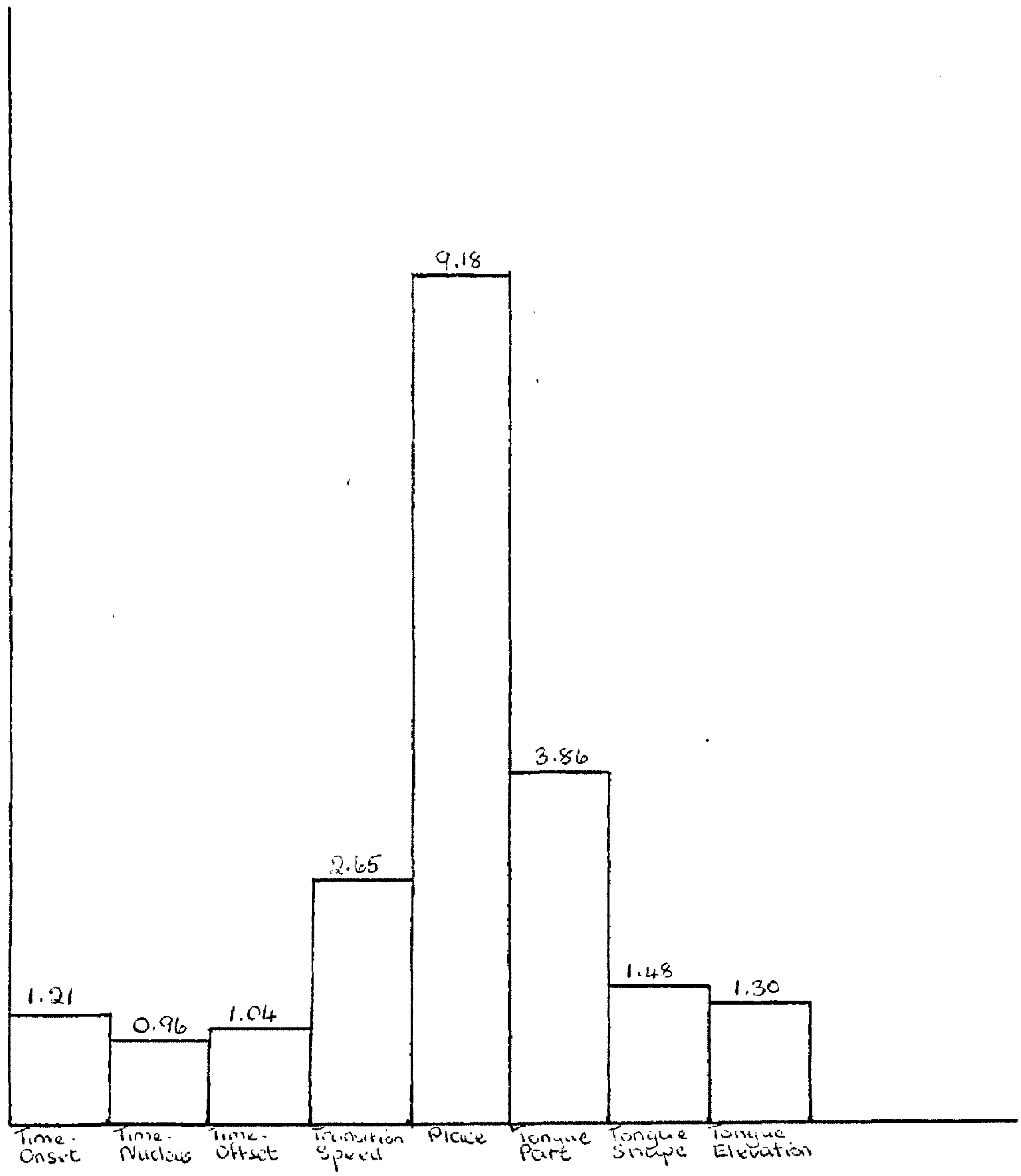

Figure 7. Validity According to Feature. Means of Scale Value Discrepancies for Each Judge Over All Phones and Order of Presentation of the Experimental Tapes.

been that the judges found it difficult to detect deviations in this area and therefore resorted to scoring what they heard and saw in the "normal" category. A similar preponderance of "normal" ratings was not evident in the judgments of the tongue features.

Time-onset feature. Showed a range of intrajudge mean discrepancy scores from 0.61 to 2.12 scale units with an interjudge mean discrepancy score of 1.21 scale units. This finding would suggest that estimations of the early or late commencement of an element of the feature bundle can validly be inferred by individual judges from the auditory and visual information available in a full face videotape, unless it is true that the preponderance of "normal" ratings is indicative of an inability to detect abnormalities in this area.

Time-nucleus feature. Showed a range of intrajudge mean discrepancy scores from 0.33 to 1.77 scale points with an interjudge mean discrepancy score of 0.96 scale points. This finding suggests that individual judges can made valid judgments about elements of the central, nucleus portion of the feature package which were adequately or inadequately maintained. The alternative explanation is that, again, the judges were unable to detect abnormalities in this area and therefore judged the stimulus as being "normal" for that feature.

Time-offset feature. Showed a range of intrajudge mean discrepancy scores from 0.34 to 1.71 scale points, with an interjudge mean discrepancy score of 1.04 scale units. This finding suggests that judges can made valid predictions from the auditory and visual information on the full face videotape about elements of the feature bundle which either finish too quickly or extend too long. Again, the alternative explanation could be that judges were unable to detect abnormalities in this area.

Tongue-shape feature. Showed intrajudge mean discrepancy scores which ranged from 0.67 to 2.90 scale units, with an interjudge mean discrepancy score of 1.48 scale units. This finding would suggest that individual judges can successfully infer from the information on the full face videotape to what extent the tongue is in a forward or retroflexed position.

Tongue elevation feature. Showed a range of intrajudge mean discrepancy scores from 0.92 to 1.92 scale points, with an interjudge mean discrepancy score of 1.30 scale points. This finding would suggest that judges can made valid judgments about the height of the tongue during the production of a phone from the auditory and visual information on a full face videotape.

Transition speed, place and tongue part. Had interjudge mean discrepancy scores of 2.65, 9.18, and 3.86 scale points respectively. This apparent inability on the part of the judges to made valid judgments from the full face videotape information could probably be reduced if a longer and more specific training program were devised. In particular, if the judges were given more opportunity to compare their judgments concerning a given phone to their perception of the phone from the x-ray view, then variability from the x-ray mean would probably decrease. The widest range of mean discrepancy scores occurred on the place feature. It may be that this could be partially accounted for by the nature of the phones under consideration. Most of the error phones were articulated in the anterior portion of the oral cavity. As was discussed earlier, the rating scale required the judges to make much finer place discriminations in the anterior region of the mouth as compared to the posterior region. Therefore, a discrepancy of 5 scale points is much closer together anatomically in the anterior region (a matter of 5 mm. at most) than it is in the posterior region. It is possible that another factor which caused a loss of validity was that the judges experienced some semantic difficulties. Some confusion arose between judges because one judge would use a specific term to designate a feature which was different from the term used by another judge. One example of this was that some judges had different meanings for "too fast" and "too late" as related to the onset feature, and this type of semantic difficulty resulted in a loss of validity. An additional factor in the loss of validity was that some of the judges were much less sophisticated than others in the use of phonetics. Some of the graduate students had been in the field of speech pathology less than a year, and while they had all been exposed to some level of education in phonetics, these students had obviously had less opportunity than others to practice these relatively new skills.

Phone

In two instances the interjudge mean discrepancy scores for phones described fell within the range of acceptability (Figure 8). The range of intrajudge mean discrepancy scores in the phone in "cake" was from 0.83 to 2.74 scale points with an interjudge mean discrepancy score of 1.68 scale points. For the phone in "seal", the intrajudge mean dis-

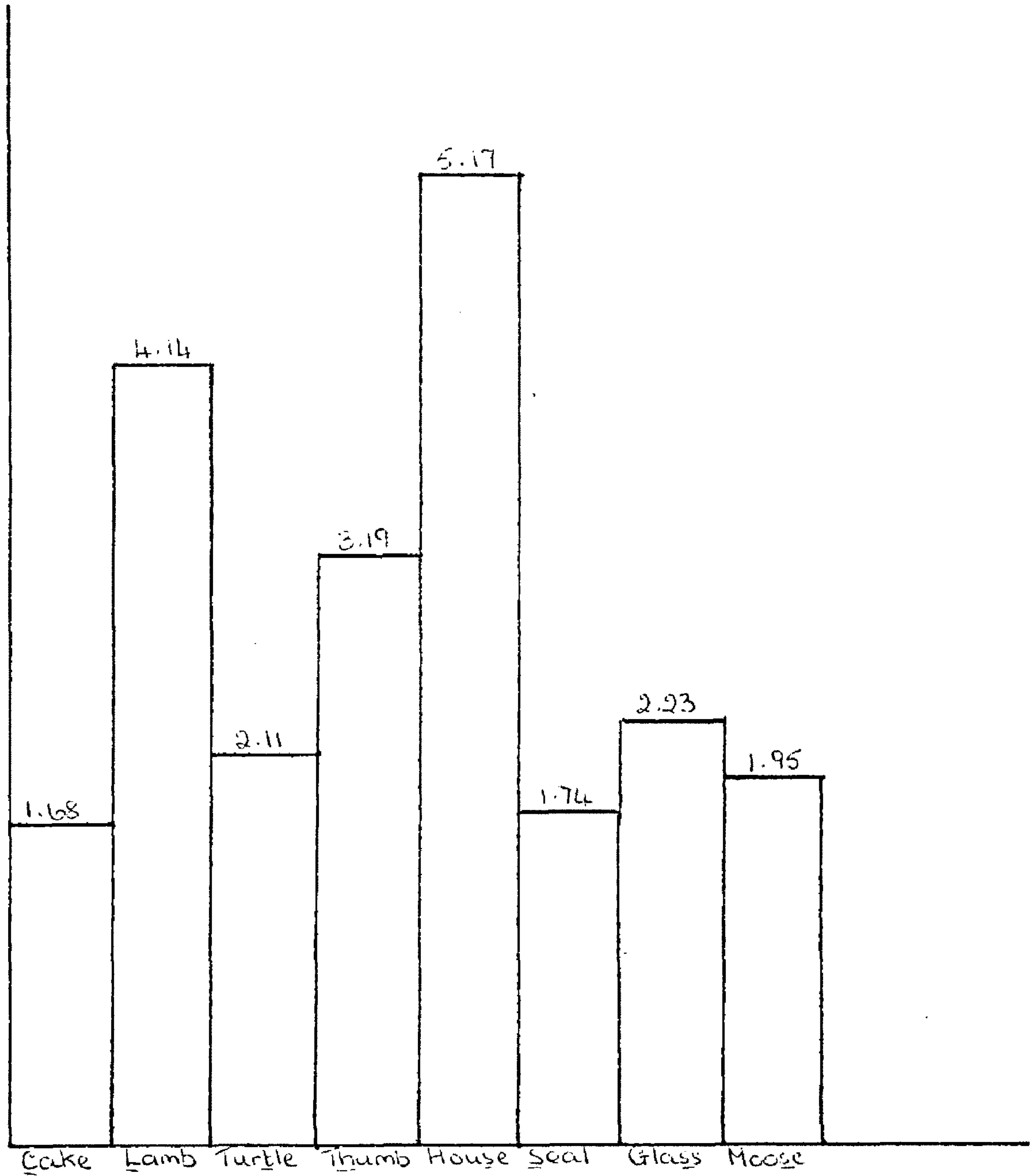

Figure 8. Validity According to Phone. Means of Scale Value Discrepancies Over All Features and Order of Presentation of the Experimental Tapes.

crepancy scores ranged from 0.66 to 2.98, with an interjudge mean discrepancy score of 1.74 scale units. In both these instances the phone used by the children was similar to /t/, although there were some differences in both the manner and spatial features involved. This finding would suggest that when the sound under consideration was fairly close to a standard phone, the judges were able to make somewhat more valid inferences about its production from the auditory and visual information on the full face videotape.

In contrast to sounds which are fairly close to phones in general use in the language, the judges had more difficulty when the phones under consideration were not as easy to associate with a standard phone of the language. For example, the phone used in "glass" could probably be most closely described as a palatal /t/ which was quite different from a phone used in our language. Consequently, the judges appeared to have more difficulty in making valid inferences about that sound.

An additional cause for the loss of validity in the description of some of the phones was that some judges failed to detect some elements of the feature bundle. When judging the phone used in "house" /hauf/, for example, some judges missed the faint terminal consonant sound and therefore described the latter part of the dipthong in that word, rather than the consonant (in addition, the full face videotape gave very limited visual clues for this sound since the child used a very lax labiodental position which looked almost bilabial and very similar to the position of his oral musculature at rest).

Order

The only variable to be considered here was order of presentation.

The results showed very little variation in validity between the first and second session exposures (Figure 9), the interjudge mean discrepancy scores being 2.74 and 2.65 scale points respectively. These values were outside the range of acceptability. This finding clearly reveals that no important variability in validity was associated with the order of presentation of the videotapes to the judges.

These findings clearly add support to the contention that judges are able to make valid inferences about features from the information on a full face videotape. It is therefore suggested that, with longer and more specific training, individual judges should be able to achieve relatively high validity of judgment over all articulatory features.

INFERENCES FROM THE STUDY

The analysis of the results suggests a number of avenues of thought. In consideration of the generally large mean discrepancy scores which were consistently associated with the place feature as compared to other features, it seems that there may have been at least three important influencing factors:

The judges were required to make particularly fine discriminatory judgments for place features in the anterior region of the oral cavity. In addition, there was a preponderance of phones produced anteriorly among the sound subsitutions of the children used for the study. These two factors may have biased the results and have produced to a large extent the higher mean discrepancy scores for this feature. Future studies might therefore include more posteriorly produced sounds for evaluation. Consideration might also be given to reducing the number

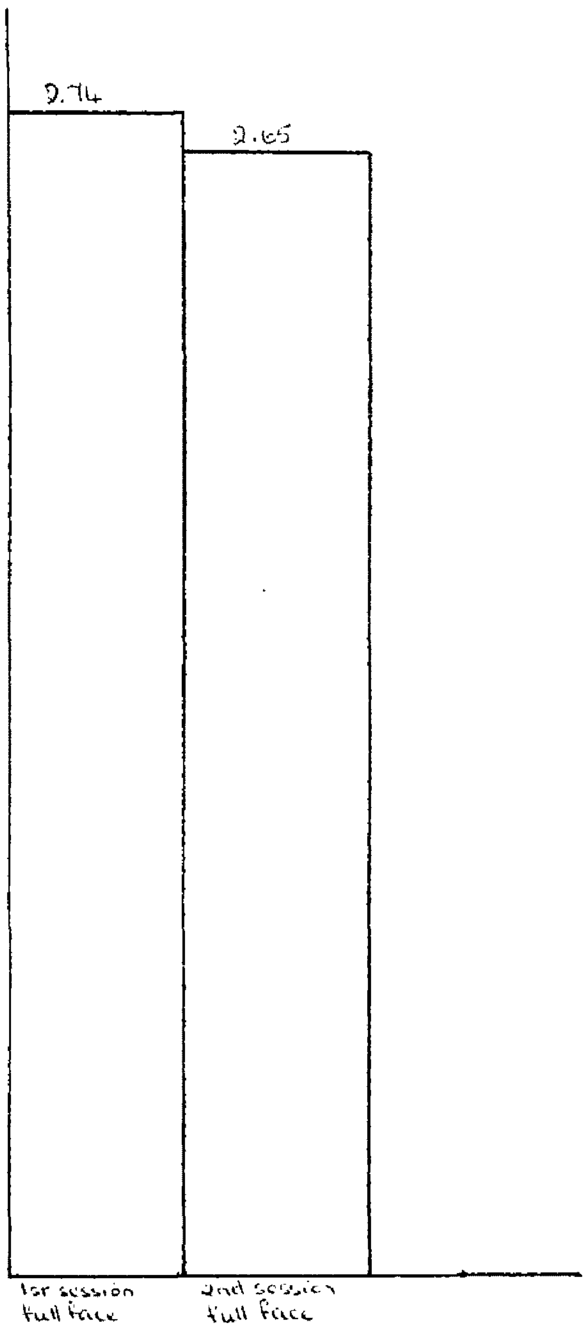

Figure 9. Validity According to Order. Means of Scale Value Discrepancies for Each Judge Over All Phones and All Features.

of scale points on the rating scale for such features as interdental, dental, and lveolar while retaining the larger rating scale for the anatomically larger areas such as the palatal and velar regions.

The judges would probably benefit from more extensive training in the concept of primary and secondary articulation. As has been pointed out, some of the judges had conflicting ideas about which was the primary and secondary articulation for a particular phone. For example, the group of judges were divided in their description of /w/, some describing the tongue position, others the lip position as the primary articulation of this pohone. Future studies might, therefore, include in the training sessions specific information about which are primary and which are secondary articulations for various phones.

Probably closely associated with the two points first mentioned in this section, the judges would benefit from specific guidance in relating the rating scale to specific anatomical locations within the oral cavity. It should be advantageous for future investigators to construct a large model or chart of the oral region which could be marked off and numbered to relate specifically to the rating scale used. Reports from the judges after the study had been completed were such that many of them were unable to remember which end of the rating scale was appropriate for the sound they wanted to evaluate; for example, several judges could not remember whether an articulation in which the lower lip was grossly inverted below the upper teeth should be rated as "labiodental 1" or "labiodental 7". Future investigators should therefore consider leaving the model or chart, with its key to the rating scale, in full view of the judges throughout the judgment session.

Another fact revealed by the results of this study was that there was very little difference between judgments made at the first session and judgments made at the second session. This was true both of the two sessions of x-ray mode and the two sessions of full face mode. This would suggest that judges did not change their opinions to any great extent as a result of successive exposures to the same material. It seems, therefore, that once judges have established their own set of standards as far as the rating scale is concerned, they are able to maintain these internal standards and apply them fairly consistently. Training sessions might, therefore, provide more early comparison between full face video presentation and x-ray presentation so that the internal standards being established in the judges are even more valid ones than was the case in the present study.

From observation during the judging sessions and from comments made later by the judges, it seemed that 30 seconds was too long a time interval between successive presentations of a given phone for most efficient judging. In many instances the judges did not wish to have the phone repeated 10 times. With the equipment available for use in this study it would have been extremely difficult to reduce the 30-second interval between each presentation of the phone, but future investigators might have the ability to reduce the time interval. In a clinical setting, if just one person were making the judgments there would, of course, be more flexibility in the number of times the judges wished to view the phone under evaluation, and he could reduce or increase the number of presentations as necessary.

CHAPTER 4

SUMMARY AND CONCLUSIONS

This study was designed to investigate the reliability and validity of the use of some articulatory distinctive features in the description of misarticulated sounds. More specifically, it was, first of all, an attempt to see whether judges, both individually and as a group, could make reliable judgments about misarticulated sounds using several distinctive features from the more traditional tool of a full face videotape, and from the more specialized tool of an x-ray videotape. Secondly, it was an attempt to compare the full face judgments to the more precise judgments of intraoral speech events obtained in reaction to the videotaped x-rays to determine how valid the judgments made from more traditional cues are.

Sixteen graduate students received an hour-long training session and then made judgments about articulatory distinctive features using a series of seven-point rating scales. The judgments described eight misarticulated phones. The judges viewed two videotapes of the identical speech act, one videotape presenting x-rays of the oral region, and the other presenting a full face view of each subject. Each tape was viewed on two occasions and judgments of the nature of the misarticulations pictured were made.

From the judgments made by each judge, sets of mean discrepancy scores were computed to evaluate the reliability of the judgments of a given phone, feature, and mode. From the discrepancy scores between the mean x-ray judgment and each full face judgment, sets of mean discrepancy scores were computed to evaluate the validity of the judgments for phone, feature and mode.

From the raw data and the statistical results of this study, the following conclusions may be drawn:

Reliability for time features, tongue shape, and tongue elevation and for the phones in "cake", "thumb", "house", and "moose" fell within the range of acceptability but was outside the range for all other features and phones. This suggested that groups of judges can generally make reliable judgments.

Validity for the features of time, tongue shape, and tongue elevation, plus the phones in "cake" and "seal". fell within the range of acceptability, which suggested that, as a group, judges can make valid judgments about all the above aspects when using the auditory and visual information of a full face videotape.

Further investigations could be carried out to determine whether a longer and more specific training program would result in greater reliability of individual judges when performing the judgment task. In particular, it would be beneficial to include in such a training program more information and experience in recognizing primary and secondary articulations of phones; more graphic representation of the rating scale to be used by marking the scale points on a model or chart; and consideration of reducing the points of the rating scale for the anterior oral region so that judges are not required to make such fine discriminations. It would also be interesting to find out whether the reliability and validity of the individual judgments would be affected if the model or chart of the scale points in the oral region were available to the judges throughout the evaluation period.

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APPENDIX A

SCRIPT OF TRAINING SESSION

Purpose of the Study

The purpose of the study is twofold. We wish to see whether it is possible for judges, who have received some training, to make judgments reliably about certain articulatory distinctive features using the auditory and visual information of a full face videotape and an x-ray videotape of the oral region. If such reliability is possible, then the information from the x-ray videotape will be used to validate the judgments made from the full face videotape.

On the tapes you will see several children, aged five to nine years, who were filmed mispronouncing some words. The full face tape and the x-ray tape depict exactly the same words as they were said simultaneously.

Procedure for Judgments

First of all an hour will be spent in training you to make the type of judgments which are necessary for this study, and then you will be shown the experimental tapes and asked to make specific judgments on the sounds indicated. The experimental tapes have been made so that you will see and hear the word 10 times at 30-second intervals. This will allow you ample time to make thoughtful judgments.

I would ask you to then return in a week's time to make similar judgments on some tapes.

Distinctive Feature Scheme

The features which have been chosen for use in this study were ones which would be most relevant to a lateral x-ray view of the oral region. Going through each of the features as they appear on your judgment forms, I will explain and demonstrate what is meant.

Rating Scale. Each feature is rated on a 1 to 7 scale in order to make the system more capable of describing individual differences. On the same "4" represents "normal", "1" represents being "too little" or "too far forward anteriorly with reference to the oral cavity"; "7" represents being "too much", "too late", or "too far back posteriorly". The points in between represent gradations on that continuum. As we go through the features, I will describe how you would rate specific elements.

Time. The time feature is broken into three sections: onset, nucleus, and offset. Onset would refer to one element of the feature bundle which occurred either too early or too late in relation to the other elements in the bundle. For example, in this production of /mi/ the lip closure element of the feature bundle of the phone /m/ occurs too soon.

*Demonstrate three times.

If you were describing that on the judgment form, it would be rated as "onset--1". Conversely, you could have the lip closure on that sound occurring too late in relation to the other elements.

*Demonstrate three times.

In that instance you would describe it as "onset--7". Nucleus is concerned with the central or nucleus part of the sound, whereas offset is concerned with the termination of the elements in the feature bundle.

Listen to the /l/ in the word /bɛl/.

*Demonstrate three times.

In that instance the voicing of the sound was continued too long, and so would be rated as "offset--7" on the judgment form.

Watch and listen to the /mi/ on the training tape as the child says /ɪts ə pɪtə əv mi/ and rate those two sounds for the time feature.

*Play training tape giving four presentations of the phrase, followed by discussion.

Transition Speed. This feature is relevant to the context in which the phone is found. It will first of all be governed by the specific context within the word, i.e. whether it is vowel/consonant, consonant/vowel, or glide. Having decided upon that aspect, the next task is to rate it on the scale. An example of normal transition speed between the /t/ and the /i/ is shown on the next section of tape.

*Demonstrate three times and discuss.

The next piece of tape gives an example of abnormal transition speed; rate the /h/ in /hɔt/.

*Play training tape four times followed by discussion.

Place. In this section you will describe the actual place of articulation. You should always describe what you consider to be the primary or most important point of articulation. In order to make these features as fine as possible, again each one is rated on the 1 to 7 scale. Listen to the way I say the /k/ in /kʌp/.

*Demonstrate twice and discuss.

Now listen to the /d/ in /dɒ/ and note that the /d/ is not made alveolarly but instead is rather dental and quite far forward so that in this instance it would be rated as "dental--2".

*Play training tape three times and discuss.

Tongue part. This feature is rated in a similar manner, once you have decided which part of the tongue was used. The terms tip, blade, and dorsum are used to designate these areas.

*Demonstrate by a sketch on the chalk board.

Listen to the /d/ in /dʊ/ again and note that here the place of articulation is with the tip of the tongue, but that it is rather far back on the tip and would therefore be rated as "tip--5".

*Play training tape three times.

Tongue shape. For this feature, the decision must first be made whether the tongue is retroflexed or forward in the mouth. The term forward is used to describe any position other than retroflexed.

*Demonstrate three times.

Once you have made that decision you must then judge the position on the rating scale. Listen to the /s/ in /sʌn/ and rate the tongue shape.

*Demonstrate three times and discuss.

Tongue elevation. The height of the tongue is the last feature included. Listen again to the /t/ in /ti/. The sound is not as "crisp" as you would expect and therefore the tongue elevation is not quite as high as would normally be expected. It would therefore be rated as "3".

*Play training tape two times and discuss.

X-rays. The x-ray tapes are to be evaluated in a similar way as the full face tapes. Look at this tape to see some of the oral landmarks.

*Play training tape of x-rays without sound while describing all the areas.

The x-rays will give you more information particularly about tongue part, shape, and elevation. When the tongue tip moves outside the oral cavity, the tip is sometimes masked by the teeth. Look at this example of /baθ/ where the /θ/ becomes a dental /t/.

*Play training tape four times.

You can see how the tongue is partially flattened out and moves forward. The elevation of the tongue is as would be expected for that sound and the tongue shape is forward. The tongue part which is used is the tip, although it is articulated rather posteriorly on the tip. This sound would be rated as:

would be rated as:	place	dental 2
	shape	forward 3
	part	tip 5
	elevation	4

Now listen to the /k/ in /dʌk/ and rate it for all features.

*Play training tape to show these x-rays 10 times and then discuss.

Listen to the /s/ in /sil/ and do the same thing.

*Play training tape to give the word 10 times and then discuss.

Now listen to the /k/ in /ki/ and judge that sound for all features.

*Play the full face training tape 10 times and then discuss.

Are there any other questions before we start the judgments on the experimental tapes?

APPENDIX B

Table 6. Scale Values for Each Feature, Each Phone, and Each Mode of Presentation of the Experimental Tapes.

Cake.

	Time – Onset				Time – Nucleus				Time – Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	NR	5	NR	5	5	4	5	5	5	5	5	5	5	5	5	4
B	5	4	1	1	4	4	4	4	NR	5	NR	5	5	11	2	2
C	NR	3	3	2	NR	5	4	4	NR	4	3	5	NR	2	4	3
D	2	2	2	2	4	5	4	5	2	2	NR	4	2	2	2	NR
E	NR	2	2	2	5	2	4	5	6	2	3	3	6	5	2	5
F	4	NR	4	3	3	NR	3	5	NR	2	5	4	5	2	19	3
G	4	4	3	2	NR	5	5	1	3	5	NR	2	5	5	3	2
H	5	2	NR	1	5	3	5	3	5	3	5	3	3	4	4	3
J	4	NR	2	3	2	4	4	2	2	2	4	3	4	3	2	3
K	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
L	5	6	2	6	4	4	4	4	NR	4	4	4	5	4	2	4
M	4	4	4	3	4	4	4	4	4	4	4	4	4	4	3	4
N	4	4	2	4	4	4	4	4	4	NR	5	4	4	2	4	4
O	5	6	3	4	4	4	4	4	4	6	4	2	4	6	6	4
P	5	3	3	3	4	4	4	4	5	3	5	4	4	12	3	5
Q	5	3	3	4	4	4	4	4	4	4	4	4	3	4	3	4
$\bar{X}$	4.25	3.75	2.88	3.06	4.00	4.00	4.13	3.88	4.00	3.69	4.19	3.75	4.20	4.69	4.19	3.60

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	37	39	34	35	8	6	3	6	4	4	4	4	5	4	4	5
B	22	27	31	28	2	7	7	2	2	1	2	2	3	6	7	1
C	33	37	37	37	5	9	10	8	2	2	2	2	3	6	5	6
D	39	37	37	39	11	10	10	10	2	2	2	2	6	NR	3	5
E	31	32	31	34	5	5	5	6	2	4	5	4	3	6	4	4
F	34	34	27	34	6	6	6	NR	2	3	6	8	5	6	5	2
G	22	31	25	33	2	5	4	4	2	4	4	4	3	4	3	4
H	31	26	33	26	8	5	5	5	3	6	3	4	4	6	4	4
J	33	32	32	30	5	5	5	4	5	3	4	2	3	6	5	3
K	19	25	27	26	5	7	7	3	2	3	3	2	5	4	NR	5
L	27	34	32	32	6	11	NR	11	3	3	2	2	4	6	6	6
M	27	24	32	26	10	12	13	10	4	2	4	3	3	4	4	4
N	27	31	33	32	7	6	10	7	3	4	3	4	3	6	4	5
O	44	30	41	30	15	8	12	13	3	4	4	2	5	6	4	5
P	27	62	35	28	3	16	13	5	3	3	3	3	3	6	4	5
Q	38	32	32	33	5	4	4	10	11	11	NR	NR	4	1	4	NR
$\bar{X}$	30.06	33.31	32.44	31.44	6.44	7.63	7.73	6.93	3.31	3.69	3.40	3.20	3.88	5.13	4.40	4.20

Table 6. Continued.

Lamb.

	Time – Onset				Time – Nucleus				Time – Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	3	2	2	3	3	1	2	2	3	2	NR	3	3	18	3	16
B	6	1	1	2	6	1	2	1	NR	NR	4	6	1	1	20	1
C	5	5	5	1	5	2	2	3	5	4	5	5	5	5	19	6
D	3	4	3	2	4	3	4	2	4	5	NR	5	4	5	4	6
E	3	6	6	6	5	6	6	6	5	6	4	6	5	2	7	4
F	3	3	5	4	3	3	5	4	5	4	5	3	3	5	3	3
G	4	3	NR	6	3	6	4	6	NR	6	NR	2	17	5	18	20
H	4	2	2	2	3	1	3	1	4	2	2	2	4	3	17	2
J	4	3	3	3	5	4	4	4	4	4	4	3	5	4	4	16
K	4	4	3	4	4	4	4	4	4	4	4	4	6	4	5	4
L	6	4	6	2	4	5	4	2	7	5	4	2	7	5	6	16
M	5	2	2	4	4	4	4	4	4	4	4	4	4	4	5	17
N	7	2	6	6	7	2	6	6	7	2	2	6	6	1	7	4
O	NR	7	5	4	4	6	4	4	4	6	3	4	4	6	6	4
P	6	6	5	5	3	3	5	4	3	3	4	3	6	NR	6	2
Q	6	3	5	3	6	3	4	3	6	3	5	3	5	3	6	3
$\bar{x}$	4.56	3.56	3.94	3.56	4.31	3.38	3.94	3.50	4.36	4.00	3.88	3.81	5.31	4.73	8.50	7.75

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	34	30	29	5	13	NR	NR	NR	4	4	NR	NR	4	1	1	NR
B	34	33	5	14	8	9	16	12	5	2	4	5	7	5	5	4
C	27	12	8	9	1	NR	NR	NR	6	4	5	4	2	2	3	1
D	34	NR	39	4	11	1	10	1	9	4	9	3	2	1	2	1
E	41	23	3	5	21	2	20	19	7	4	6	6	4	2	5	4
F	38	63	30	6	2	20	2	16	1	9	6	6	1	2	5	2
G	41	34	17	23	20	13	3	6	5	1	4	4	6	6	4	4
H	34	33	9	13	13	3	3	5	5	3	NR	5	4	3	2	5
J	30	36	32	NR	5	11	5	4	3	3	4	4	2	1	5	1
K	39	NR	33	4	10	11	5	NR	10	2	2	2	7	1	6	5
L	38	35	4	6	10	11	6	3	4	4	6	3	5	6	4	3
M	28	35	27	6	12	13	NR	NR	4	6	4	4	4	2	2	4
N	40	42	30	1	14	9	12	NR	7	5	5	4	5	5	7	5
O	27	4	39	4	2	NR	11	NR	3	4	4	4	NR	4	6	4
P	31	29	35	30	7	5	7	2	2	8	12	12	3	3	3	3
Q	5	4	4	40	NR	NR	NR	12	11	4	4	NR	4	1	1	NR
$\bar{x}$	32.56	29.50	21.50	11.33	9.93	9.00	8.33	8.00	5.38	4.19	5.36	4.57	4.00	2.81	3.81	3.99

Table 6. Continued.

Turtle.

	Time-Onset				Time-Nucleus				Time-Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	4	5	4	5	4	5	4	4	4	5	3	4	4	10	4	4
B	NR	4	4	4	4	4	5	4	NR	4	NR	4	4	4	6	4
C	3	2	2	2	5	4	5	4	3	3	2	5	3	3	3	2
D	2	2	2	3	4	5	3	6	2	3	2	3	2	2	2	2
E	3	2	2	2	3	2	4	5	3	2	2	2	16	9	16	2
F	3	NR	1	2	5	3	3	3	5	3	2	3	5	16	16	17
G	NR	3	3	3	4	4	NR	4	NR	5	6	5	9	9	3	10
H	4	2	6	4	4	3	5	4	4	2	5	4	10	3	NR	17
J	2	4	1	6	4	4	4	6	4	4	4	4	15	18	15	4
K	4	5	4	4	4	5	4	4	4	5	4	4	4	3	3	4
L	3	6	2	6	4	4	4	4	2	4	2	4	2	4	2	4
M	4	6	2	4	4	4	4	4	4	4	2	4	4	17	4	11
N	5	4	1	4	4	4	3	4	4	4	4	4	18	9	1	9
O	4	3	2	4	4	4	4	4	5	2	6	6	10	9	9	10
P	5	3	5	4	5	4	6	4	6	5	2	3	3	4	3	10
Q	3	5	2	3	3	5	2	3	3	5	2	3	3	5	2	3
$\bar{X}$	3.56	3.75	2.69	3.75	4.06	4.00	4.00	4.19	3.81	3.75	3.35	3.88	7.00	7.81	5.93	7.06

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	40	37	31	34	13	12	5	5	4	4	5	4	4	4	4	4
B	36	38	37	35	8	14	19	6	3	3	6	2	5	5	3	2
C	36	38	31	34	10	10	6	9	5	4	2	3	7	5	5	5
D	39	39	39	37	11	11	11	9	2	3	2	2	5	4	2	2
E	37	34	33	30	7	7	5	5	2	3	4	6	5	6	4	5
F	37	NR	30	37	7	6	6	6	4	3	9	6	5	5	3	3
G	37	34	32	31	6	6	4	4	6	4	3	4	5	4	4	4
H	23	31	32	34	6	6	10	6	9	2	5	3	6	3	5	2
J	31	36	32	30	5	9	13	6	4	4	4	2	5	6	4	3
K	36	30	42	32	NR	12	2	9	3	3	3	3	6	5	6	6
L	32	34	34	34	11	9	6	11	3	3	4	2	6	6	4	5
M	30	33	36	31	10	11	9	10	3	6	4	5	3	4	4	4
N	37	36	33	30	13	1	12	5	6	7	10	3	7	5	5	6
O	40	42	35	29	13	20	6	8	NR	6	5	3	7	6	4	3
P	36	36	31	NR	11	9	10	6	4	3	6	4	5	6	4	3
Q	34	33	34	33	8	12	NR	5	5	5	11	12	5	5	5	NR
$\bar{X}$	36.00	35.40	33.88	32.73	9.27	9.56	8.27	6.88	4.20	3.94	5.19	4.00	5.38	4.94	4.13	3.80

Table 6. Continued.

Thumb.

	Time - Onset				Time - Nucleus				Time - Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	NR	3	1	4	1	2	2	3	2	NR	2	4	3	3	17	18
B	7	1	1	5	2	2	NR	4	NR	4	NR	3	1	1	2	3
C	6	5	4	5	6	4	NR	4	5	4	5	5	5	5	5	6
D	2	3	4	2	4	3	4	5	5	5	NR	5	12	5	19	5
E	3	2	6	2	4	6	6	5	5	6	6	6	3	6	6	6
F	2	5	5	5	6	3	NR	3	7	5	4	5	14	5	3	4
G	2	3	3	NR	4	6	NR	6	NR	6	NR	2	3	3	2	6
H	1	2	1	3	2	3	2	4	2	2	2	3	3	3	17	16
J	2	4	4	4	2	2	6	4	2	2	6	2	18	16	19	16
K	4	2	4	4	4	2	4	4	4	2	4	4	4	11	3	4
L	6	4	6	6	4	4	4	6	6	4	6	6	20	18	20	20
M	2	5	2	4	4	4	4	4	4	4	NR	4	4	18	4	18
N	6	7	7	6	6	7	5	6	6	7	7	6	1	3	7	6
O	3	3	3	4	4	4	4	4	2	3	5	4	3	2	4	4
P	6	5	4	4	5	4	NR	4	4	5	5	3	5	12	5	4
Q	5	3	5	5	5	3	5	5	5	3	5	5	5	3	5	5
$\bar{X}$	3.81	3.56	3.75	4.19	3.94	3.69	4.13	4.44	4.19	4.13	4.56	4.19	6.50	7.13	8.63	8.81

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	38	29	3	5	12	13	NR	NR	4	4	2	NR	5	NR	2	2
B	39	33	2	2	18	20	19	NR	5	6	5	NR	6	6	6	NR
C	10	12	8	9	1	NR	NR	6	7	5	5	5	2	2	2	4
D	4	4	4	4	NR	1	NR	1	7	6	5	6	2	1	2	1
E	27	4	2	4	5	5	NR	2	6	5	4	3	1	4	3	2
F	40	5	29	51	19	20	3	16	2	3	2	6	2	3	1	2
G	40	13	13	14	17	20	5	NR	2	4	5	NR	5	6	6	NR
H	31	31	3	3	10	6	17	NR	6	2	NR	NR	3	3	2	NR
J	29	39	53	NR	4	18	NR	11	4	NR	4	4	1	4	1	2
K	4	2	4	4	NR	NR	NR	NR	9	2	2	2	2	2	2	1
L	5	3	4	3	NR	NR	NR	11	4	4	4	4	1	6	4	5
M	36	4	5	5	NR	NR	NR	NR	NR	4	NR	7	NR	4	NR	2
N	1	1	4	1	17	NR	NR	NR	6	5	3	3	7	6	3	2
O	4	4	4	2	NR	NR	NR	NR	NR	4	NR	4	NR	5	NR	6
P	41	5	NR	2	18	12	NR	NR	5	3	3	3	4	3	2	2
Q	4	4	5	5	NR	20	NR	NR	4	NR	4	4	4	NR	4	4
$\bar{X}$	9.53	12.06	9.53	13.50	12.10	13.50	11.00	7.83	5.07	4.07	3.69	4.25	3.21	3.93	2.86	2.69

Table 6. Continued.

House.

	Time - Onset				Time-Nucleus				Time - Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	NR	2	2	3	1	1	2	2	1	2	3	NR	10	10	11	10
B	1	1	2	2	7	1	NR	1	NR	2	5	1	6	8	14	14
C	1	3	3	3	2	3	4	5	7	4	3	3	8	11	9	9
D	1	2	1	2	1	3	1	1	1	5	NR	6	8	16	8	9
E	4	4	NR	3	6	6	4	4	7	6	3	4	9	9	10	9
F	7	4	4	3	7	3	6	3	7	5	6	3	17	10	17	10
G	1	2	NR	4	1	6	3	6	7	6	NR	6	14	9	12	11
H	1	1	3	1	1	2	2	1	1	NR	3	1	8	15	10	9
J	4	2	4	2	6	NR	6	2	2	1	5	2	11	8	11	9
K	4	4	6	4	4	3	2	3	4	3	3	3	11	9	13	11
L	4	4	3	4	4	4	4	4	4	4	4	4	11	11	10	11
M	4	4	4	NR	4	4	4	4	4	4	4	4	NR	16	11	12
N	7	NR	5	4	7	1	3	4	7	1	5	4	8	8	11	11
O	4	5	5	3	5	4	3	4	6	6	3	3	11	9	11	10
P	4	3	5	5	5	3	4	4	3	3	5	4	13	12	11	13
Q	4	3	5	4	4	3	5	4	4	3	5	4	11	10	11	11
$\bar{X}$	3.44	3.00	3.75	3.19	4.06	3.19	3.56	3.25	4.31	3.69	4.06	3.50	10.40	10.69	11.25	10.56

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	47	47	9	10	19	16	NR	NR	3	6	NR	NR	1	1	1	2
B	48	46	24	12	17	17	21	NR	3	6	7	NR	2	6	2	NR
C	59	13	13	11	21	4	NR	NR	6	4	5	3	2	6	6	2
D	22	11	8	12	1	11	NR	9	11	5	4	5	2	2	1	2
E	61	47	11	63	19	13	19	20	6	6	4	6	6	6	4	2
F	41	55	2	5	20	20	2	6	10	3	2	3	5	3	2	2
G	40	37	10	13	8	12	NR	18	2	3	4	4	4	6	5	5
H	23	41	9	10	9	1	NR	NR	1	2	10	NR	1	3	2	NR
J	46	30	9	11	18	11	NR	4	5	4	4	4	5	4	2	2
K	40	15	11	9	21	7	NR	2	13	1	2	2	5	3	2	3
L	8	9	8	9	NR	4	NR	NR	4	9	4	4	4	2	2	5
M	32	37	10	12	11	9	NR	NR	4	6	NR	6	6	2	NR	2
N	8	63	8	8	11	NR	NR	NR	4	6	NR	2	5	6	NR	2
O	25	61	8	13	2	4	NR	NR	2	6	NR	4	7	5	NR	5
P	39	26	9	8	14	11	2	11	5	3	3	3	5	3	4	2
Q	10	47	9	16	NR	19	NR	NR	4	NR	4	4	4	5	5	5
$\bar{X}$	34.31	36.56	9.88	13.50	13.64	10.60	11.00	10.00	5.19	4.67	4.12	3.85	4.00	3.94	2.92	2.93

Table 6. Continued.

Seal

	Time-Onset				Time-Nucleus				Time - Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	2	2	1	2	2	1	1	1	3	3	2	NR	3	3	10	3
B	1	6	1	7	NR	1	6	1	NR	NR	2	1	NR	NR	1	7
C	3	2	5	3	5	4	4	5	2	3	3	4	2	NR	3	3
D	5	2	2	2	4	5	3	5	NR	2	NR	5	2	2	4	2
E	1	2	3	2	2	2	3	2	2	2	3	2	3	2	3	2
F	3	4	2	5	5	3	5	3	5	5	5	5	5	5	3	5
G	6	3	NR	4	1	6	4	5	NR	6	NR	5	1	6	4	5
H	3	5	3	6	2	2	2	3	3	4	3	4	2	4	3	NR
J	4	3	4	3	4	4	4	3	4	4	4	4	4	4	5	4
K	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	3
L	3	4	6	3	4	2	4	3	4	NR	5	4	4	7	5	4
M	3	5	4	4	4	4	4	4	4	4	4	4	4	4	4	3
N	6	3	3	5	6	1	4	4	6	1	3	4	6	NR	2	3
O	6	6	6	3	5	4	5	4	5	5	5	3	5	5	4	4
P	4	3	3	6	5	4	4	5	3	5	4	5	4	5	5	5
Q	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4
$\bar{x}$	3.63	3.56	3.50	3.94	3.81	3.19	3.81	3.50	3.81	3.75	3.69	3.88	3.53	4.23	4.00	3.80

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	34	34	26	34	12	12	5	8	4	5	4	2	5	6	5	6
B	22	37	36	23	6	18	6	7	1	5	5	11	6	6	7	NR
C	25	24	40	34	5	2	10	3	2	4	5	5	6	5	5	4
D	34	37	33	37	10	11	6	11	4	5	2	2	6	6	3	6
E	40	30	33	32	18	4	5	6	6	2	5	3	5	6	4	3
F	23	40	24	33	7	6	10	5	6	3	3	5	6	5	3	3
G	16	28	24	30	2	6	2	5	4	4	3	4	6	5	4	5
H	34	30	24	26	12	6	12	6	4	5	3	5	5	6	2	3
J	33	32	31	30	5	4	5	5	5	4	4	3	5	4	5	3
K	26	26	28	26	9	11	2	4	NR	3	2	2	5	5	5	5
L	34	34	26	33	7	11	6	11	3	2	3	3	5	6	3	6
M	32	31	32	30	13	10	10	10	2	3	4	3	5	6	4	5
N	35	35	24	32	8	12	3	11	3	5	2	4	6	5	3	4
O	35	37	37	30	8	12	18	8	3	2	2	2	5	5	6	6
P	28	29	33	30	7	7	7	6	3	5	3	4	3	NR	4	5
Q	33	34	33	36	6	12	6	5	13	NR	5	12	NR	NR	4	NR
$\bar{x}$	30.25	32.38	30.25	31.00	8.44	9.00	7.06	6.94	4.19	3.80	3.44	3.75	5.27	5.43	4.19	4.57

Table 6 Continued.

Glass

	Time - Onset				Time - Nucleus				Time - Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	2	2	2	2	2	1	1	1	NR	NR	1	2	11	11	11	17
B	1	NR	1	1	6	2	1	1	NR	NR	NR	1	9	NR	13	13
C	5	4	5	4	3	3	3	4	5	6	5	5	12	12	12	10
D	2	4	1	4	1	2	1	2	NR	5	NR	6	11	11	10	13
E	4	2	2	2	7	6	3	2	6	6	6	6	11	9	9	9
F	2	3	3	3	2	3	5	3	2	5	5	5	11	10	11	10
G	NR	7	NR	NR	2	7	2	2	NR	7	6	2	11	13	12	11
H	1	1	1	1	1	1	2	2	3	1	2	2	12	9	9	10
J	4	4	4	4	4	1	7	4	4	1	7	2	11	9	11	11
K	6	4	5	4	3	3	2	2	3	2	2	2	10	4	12	4
L	4	3	4	3	4	1	4	6	4	7	6	6	11	11	11	13
M	4	4	4	4	4	4	4	4	3	4	4	4	11	NR	11	12
N	7	2	7	1	7	2	7	1	7	2	7	1	13	8	13	8
O	6	4	2	4	4	4	3	4	4	6	4	2	12	4	20	11
P	5	5	5	5	4	4	5	5	4	3	3	2	11	9	10	9
Q	6	3	6	3	6	3	6	4	6	3	6	4	11	10	12	10
$\bar{X}$	3.94	3.50	3.50	3.06	3.75	2.94	3.60	2.94	4.19	4.13	4.50	3.25	11.13	9.29	11.69	10.69

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface	1st sess x-ray	2nd sess x-ray	1st sess fullface	2nd sess fullface
A	35	33	31	34	12	5	4	6	3	4	4	3	2	6	6	5
B	35	33	23	32	15	NR	3	4	5	NR	2	3	6	NR	3	NR
C	30	30	28	30	2	3	2	2	3	3	5	3	3	4	3	3
D	32	37	30	33	9	NR	5	11	4	5	11	4	2	1	2	2
E	10	31	23	34	10	5	3	6	3	4	6	5	3	5	2	5
F	17	30	23	55	13	2	5	2	4	5	2	2	3	3	3	3
G	34	37	30	26	12	9	11	2	5	3	3	4	6	4	4	4
H	31	30	31	31	12	6	9	5	2	5	5	5	2	5	2	6
J	32	30	32	32	5	4	6	4	4	4	4	4	5	4	2	4
K	24	28	35	26	2	13	6	7	2	3	10	3	3	6	6	5
L	29	30	32	29	NR	4	1	2	2	2	3	2	4	4	4	5
M	61	30	39	37	19	9	NR	12	NR	5	NR	4	3	2	NR	4
N	34	47	41	44	8	16	17	18	3	5	5	3	3	3	4	3
O	26	30	30	29	6	9	7	9	4	2	3	2	3	4	6	6
P	28	33	31	35	6	9	9	4	9	6	10	4	2	5	3	5
Q	26	39	34	33	6	12	2	12	6	NR	4	12	6	NR	4	NR
$\bar{X}$	30.25	33.13	30.69	33.75	9.13	7.57	6.00	6.63	3.93	4.00	5.13	3.94	3.50	4.00	3.60	4.29

Table 6. Continued.

Moose.

	Time - Onset				Time - Nucleus				Time - Offset				Transition Speed			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	4	4	4	4	4	3	4	3	NR	4	4	4	11	11	11	12
B	7	NR	2	NR	6	NR	7	4	1	NR	NR	5	12	NR	14	11
C	3	5	5	4	5	4	4	4	4	4	4	4	11	11	9	11
D	2	2	2	2	3	5	2	5	3	3	NR	4	10	9	9	9
E	4	3	4	2	4	6	3	6	3	4	3	3	10	9	10	10
F	3	5	3	3	3	4	3	3	5	4	5	3	10	10	12	12
G	NR	5	NR	3	4	6	4	4	NR	6	NR	4	11	12	12	10
H	4	5	4	5	4	6	4	5	4	5	4	6	11	NR	11	9
J	4	4	4	4	4	2	4	3	3	3	4	3	11	11	10	11
K	4	4	4	4	5	3	4	4	5	3	4	5	11	NR	11	11
L	5	4	4	4	4	4	4	4	4	4	4	4	12	11	11	11
M	4	4	4	4	4	4	4	4	4	4	4	5	11	12	11	12
N	4	5	4	4	4	5	4	4	4	5	4	4	NR	10	10	11
O	4	3	4	4	4	3	4	4	3	4	4	2	NR	10	11	11
P	5	4	5	4	4	5	4	4	3	NR	4	5	10	12	11	11
Q	4	4	4	4	4	4	4	4	4	4	4	4	11	11	11	11
X̄	4.06	4.06	3.81	3.69	4.13	4.25	3.94	4.06	3.63	4.06	4.00	4.06	10.86	10.69	10.88	10.81

	Place				Tongue Part				Tongue Shape				Tongue Elevation			
	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face	1st sess x-ray	2nd sess x-ray	1st sess full face	2nd sess full face
A	19	16	21	9	6	5	12	7	3	1	4	6	2	1	2	1
B	30	NR	34	36	7	NR	8	9	1	NR	1	1	1	NR	2	NR
C	12	11	10	13	2	3	1	NR	2	1	5	4	3	1	1	2
D	18	17	16	17	4	2	1	2	4	2	1	2	2	2	5	2
E	12	24	30	24	1	6	4	4	10	4	11	3	2	4	5	5
F	31	19	16	NR	19	12	12	19	3	4	3	2	3	2	3	2
G	30	22	31	23	6	1	11	6	2	11	4	2	5	2	4	3
H	19	17	20	9	11	5	12	3	11	9	10	2	3	2	2	3
J	20	8	33	29	6	2	5	6	2	2	4	3	2	2	2	3
K	25	16	27	17	7	2	2	2	9	2	2	2	2	2	3	3
L	18	18	23	20	4	4	5	2	2	1	3	1	4	2	4	4
M	26	26	27	27	10	10	11	6	3	3	4	3	6	4	4	3
N	16	16	23	21	6	6	2	10	3	1	1	1	2	2	3	4
O	22	20	23	20	1	8	1	5	1	3	1	4	2	4	6	2
P	9	9	34	30	5	NR	8	9	3	3	3	3	3	4	3	3
Q	28	22	30	22	4	3	4	5	1	3	5	3	2	2	4	NR
X̄	20.94	17.40	25.50	21.13	6.19	4.93	6.19	6.33	3.75	3.33	3.88	2.63	2.75	2.40	3.31	2.86

APPENDIX C

Table 7. Discrepancies in Scale Points Between First and Second X-ray Presentation and First and Second Full Face Presentation. Judgment Discrepancies for "Cake"

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Interjudge $\bar{x}$
Time-Onset	x-ray	—	-1	—	0	—	—	0	-3	—	0	1	0	0	1	-2	-2	0.91
	full face	—	0	-1	0	0	-1	-1	—	1	0	4	-1	2	1	0	1	0.93
Time-Nucleus	x-ray	-1	0	—	1	-3	—	—	-2	2	0	0	0	0	0	0	0	0.69
	full face	0	0	0	1	1	2	-4	-2	-2	0	0	0	0	0	0	0	0.75
Time-Offset	x-ray	0	—	—	0	-4	—	2	-2	0	0	—	0	—	2	-2	0	1.09
	full face	0	—	2	—	0	-1	—	-2	-1	0	0	0	-1	-2	-1	0	0.77
Transition Speed	x-ray	0	7	—	0	-1	-3	0	1	-1	0	-1	0	-2	2	8	1	1.80
	full face	-1	0	-1	—	3	-16	-1	-1	1	0	2	1	0	-1	2	1	2.00
Place	x-ray	2	5	4	-2	1	10	-1	-5	-1	6	7	-3	4	-14	35	-6	6.63
	full face	1	-3	0	2	3	7	8	-7	-2	-1	0	-6	-1	-11	-7	1	3.75
Tongue Part	x-ray	-2	5	4	-1	0	0	3	3	0	2	5	2	-1	-7	13	-1	3.06
	full face	3	-5	-2	0	1	—	0	0	-1	-4	—	-3	-3	1	-8	4	2.50
Tongue Shape	x-ray	0	-1	0	0	2	1	2	3	-2	1	0	-2	1	1	0	0	1.00
	full face	0	0	0	0	-1	2	0	1	-2	-1	0	-1	1	-2	0	0	0.69
Tongue Elevation	x-ray	-1	3	3	—	3	1	1	2	3	-1	2	1	3	1	3	-3	2.07
	full face	1	-6	1	2	0	-3	1	0	-2	—	0	0	1	1	1	—	1.36

Table 7. Continued. Judgment Discrepancies for "Lamb".

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Interjudge
Time Onset	x-ray	-1	-5	0	1	3	0	-1	-2	-1	0	-2	-3	-5	—	0	-3	1.80
	fullface	1	1	-4	-1	0	-1	—	0	0	1	-4	2	0	-1	0	-2	1.20
Time Motions	x-ray	-2	-5	-3	-1	1	0	3	-2	-1	0	1	0	-5	2	0	-3	1.81
	fullface	0	-1	1	-2	0	-1	2	-2	0	0	-2	0	0	0	-1	-1	0.81
Time Offset	x-ray	-1	0	-1	1	1	-1	—	-2	0	0	-2	0	-5	2	0	-3	1.27
	fullface	—	2	0	—	2	-2	—	0	-1	0	-2	0	4	1	-1	-2	1.31
Transition Spurt	x-ray	15	0	0	1	-3	2	-14	-1	-1	-2	-2	0	-5	2	—	-3	3.40
	fullface	13	-19	-13	2	-3	0	2	15	12	-1	10	12	-3	-2	-4	-3	7.13
Place	x-ray	-4	-1	-15	—	-18	25	-7	-1	6	—	-3	7	2	-23	-2	-1	7.67
	fullface	-24	9	1	-35	2	-24	6	4	—	-29	2	-21	-29	-35	-5	36	17.47
Tongue Part	x-ray	—	6	—	-10	-19	18	-7	-10	6	1	1	1	-5	—	-2	0	6.62
	fullface	0	-4	0	-9	-1	14	3	2	-1	—	-3	0	—	—	-5	—	3.50
Tongue Shape	x-ray	0	-3	-2	-5	-3	8	-4	-2	0	-8	0	2	-2	1	1	-7	3.00
	fullface	0	1	-1	-6	0	0	0	—	0	0	-3	0	-1	0	0	—	0.86
Tongue Elevation	x-ray	-3	-2	0	-1	-2	1	0	-1	-1	-6	-1	-2	0	—	0	-3	1.40
	fullface	—	-1	-2	-1	-1	-3	0	3	-4	-1	-1	2	-2	-2	0	—	1.64

Table 7. Continued. Judgment Discrepancies for "Turtle".

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Interjudge $\bar{X}$
Time-Onset	x-ray	1	—	-1	0	-1	—	—	-2	2	1	3	2	-1	-1	-2	2	1.46
	fullface	1	0	0	1	0	1	0	-2	5	0	4	2	3	2	-1	1	1.44
Time-Nucleus	x-ray	1	0	-1	1	-1	-2	0	-1	0	1	0	0	0	0	-1	2	0.75
	fullface	0	-1	-1	3	1	0	—	-1	2	0	0	0	1	0	-2	1	0.87
Time-Offset	x-ray	1	—	0	1	-1	-2	—	-2	0	1	2	0	0	-3	-1	2	1.14
	fullface	1	—	3	1	0	1	-1	-1	0	0	2	2	0	0	1	1	0.93
Transition Duration	x-ray	6	0	0	0	-7	11	0	-7	3	-1	2	13	-4	-1	1	2	3.63
	fullface	0	-2	-1	0	-14	1	7	—	-11	1	2	7	8	1	7	1	4.20
Place	x-ray	-3	2	3	0	-3	—	-3	8	5	-6	2	3	-1	0	0	-1	2.67
	fullface	3	-2	3	-2	-3	7	-1	2	-2	-10	0	-5	-3	-6	—	-1	3.33
Tongue Root	x-ray	-1	6	0	0	0	-1	0	0	4	—	-2	1	-12	7	-2	2	2.53
	fullface	0	-13	3	-2	0	0	0	-4	-7	7	5	1	-7	2	-4	—	3.67
Tongue Shape	x-ray	0	0	-1	1	1	-1	-2	-7	0	0	0	3	1	—	-1	0	1.20
	fullface	-1	-4	1	0	2	-3	1	-2	-2	0	-2	1	-7	-2	-2	1	1.94
Tongue Blade	x-ray	0	0	-2	-1	1	0	-1	-3	1	-1	0	1	-2	-1	1	0	0.94
	fullface	0	-1	0	0	1	0	0	-3	-1	0	1	0	1	-1	-1	—	0.67

Table 7. Continued. Judgment Discrepancies for "Thumb"

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Interjudge $\bar{x}$
Time Onset	x-ray	—	-6	-1	1	-1	3	1	1	2	-2	-2	3	1	0	-1	-2	1.80
	fullface	3	4	1	-2	-4	0	—	2	0	0	0	2	-1	1	0	0	1.33
Time Nucleus	x-ray	1	0	-2	-1	2	-3	2	1	0	-2	0	0	1	0	-1	-2	1.13
	fullface	1	—	—	1	-1	—	—	2	-2	0	2	0	1	0	—	0	1.09
Time Offset	x-ray	—	—	-1	0	1	-2	—	0	0	-2	-2	0	1	1	1	2	1.00
	fullface	2	—	0	—	0	1	—	1	-4	0	0	—	-1	-1	-2	0	1.00
Transition Speed	x-ray	0	0	0	-7	3	-9	0	0	-2	7	-2	14	2	-1	7	-2	3.50
	fullface	1	1	1	-14	0	1	4	-1	-3	1	0	14	-1	0	-1	0	2.69
Place	x-ray	1	-6	2	0	-23	-35	-27	0	10	-2	-2	-32	0	0	-36	0	11.00
	fullface	2	0	6	0	2	22	1	0	—	0	-1	0	-3	-2	—	0	2.79
Tongue Root	x-ray	1	2	—	—	0	1	3	-4	14	0	0	0	—	0	-6	—	2.58
	fullface	0	—	—	—	—	13	—	—	—	0	—	0	0	0	0	0	1.63
Tongue Shape	x-ray	0	1	-2	-1	-1	1	2	-4	—	-7	0	—	-1	—	-2	—	1.83
	fullface	—	—	0	1	-1	4	—	0	0	0	0	—	0	—	1	0	1.40
Tongue Elevation	x-ray	—	0	0	-1	3	1	1	0	3	0	5	—	-1	—	-1	—	1.33
	fullface	0	—	2	-1	-1	1	—	—	1	-1	1	—	-1	—	0	0	1.20

Table 7. Continued. Judgment Discrepancies for "House".

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Inter-judge $\bar{x}$
Time Onset	X-ray	–	0	2	1	0	-3	1	0	-2	0	0	0	–	1	-1	-1	0.86
	fullface	1	0	0	1	–	-1	–	-2	-2	-2	1	–	-1	-2	0	-1	1.08
Time Nucleus	X-ray	0	-6	1	2	0	-4	5	1	–	-1	0	0	-6	-1	-2	-1	2.00
	fullface	0	–	1	0	0	-3	3	-1	-4	1	0	0	1	1	0	-1	1.07
Time Offset	X-ray	1	–	-3	4	-1	-2	-1	–	-1	-1	0	0	-6	0	0	-1	1.50
	fullface	–	-4	0	–	1	-3	–	-2	-3	0	0	0	-1	0	-1	-1	1.23
Transition Speed	X-ray	0	2	3	8	0	-7	-5	7	-3	-2	0	–	0	-2	-1	-1	2.73
	fullface	-1	0	0	1	-1	-7	-1	-1	-2	-2	1	1	0	-1	2	0	1.31
Place	X-ray	0	-2	-46	-11	-14	14	-3	18	-16	-25	1	5	55	36	-13	37	18.50
	fullface	1	-12	-2	4	52	3	3	1	2	-2	1	2	0	5	-1	1	5.75
Tongue [illegible]	X-ray	-3	0	-17	10	-6	0	4	-8	-7	-14	–	-2	–	2	-3	–	6.85
	fullface	0	–	0	–	1	4	–	0	–	–	0	0	0	0	9	0	1.27
Tongue [illegible]	X-ray	3	3	-2	-6	0	-7	1	1	-1	-12	5	2	2	4	-2	–	3.40
	fullface	0	–	-2	1	2	1	0	–	0	0	0	–	–	–	0	0	0.55
Tongue [illegible]	X-ray	0	4	4	0	0	-2	2	2	-1	-2	-2	-4	1	-2	-2	1	1.81
	fullface	1	–	-4	1	-2	0	0	–	0	1	3	–	–	–	-2	0	1.27

Table 7. Continued. Judgment Discrepancies for "Seal".

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Interjudge $\bar{x}$
Time Onset	x-ray	0	5	-1	-3	1	1	-3	2	-1	-1	1	2	-3	0	-1	0	1.56
	fullface	1	6	-2	0	-1	3	–	3	-1	0	-3	0	2	-3	3	-1	1.93
Time Nucleus	x-ray	-1	–	-1	1	0	-2	-5	0	0	0	-2	0	-5	-1	-1	0	1.27
	fullface	0	-5	1	2	-1	-2	1	1	-1	0	-1	0	0	-1	1	0	1.06
Time Offset	x-ray	0	0	1	–	0	0	–	1	1	1	–	1	-5	0	2	0	0.92
	fullface	–	-1	1	–	-1	0	–	1	0	0	-1	0	1	-2	1	0	0.69
Transition [illegible]	x-ray	0	0	–	0	-1	0	5	2	0	0	3	0	–	0	1	0	0.86
	fullface	-7	6	0	-2	-1	2	1	–	-1	-1	-1	-1	1	0	0	0	1.60
Place	x-ray	0	15	-1	3	-10	17	7	-4	-1	0	0	-1	0	2	1	1	3.94
	fullface	-2	-13	-6	4	-1	9	6	2	-1	-2	7	-2	8	-7	-3	3	4.75
Tongue Part	x-ray	0	12	-3	1	-14	-1	-4	-6	-1	2	4	-3	9	4	0	12	4.75
	fullface	3	1	-7	5	1	-5	3	-6	0	2	5	0	8	-10	-1	-1	3.63
Tongue [illegible]	x-ray	1	4	2	1	-4	-3	0	1	-1	–	-1	-1	2	-1	2	–	1.50
	fullface	-2	6	0	0	-2	2	1	2	-1	0	0	-1	2	0	1	7	1.69
Tongue Height	x-ray	1	0	-1	0	1	-1	-1	1	-1	0	1	1	-1	0	–	0	0.67
	fullface	1	–	-1	3	-1	0	1	1	-2	0	3	1	1	0	1	–	1.07

Table 7 Continued   Judgment Discrepancies for "Glass".

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Inter-judge $\bar{x}$
Time-Onset	x-ray	0	–	-1	2	-2	1	–	0	0	-2	-1	0	-5	-2	0	-3	1.36
	fullface	0	0	-1	3	0	0	0	0	0	-1	-1	0	-6	2	0	-3	1.06
Time-Nucleus	x-ray	-1	-4	0	1	-1	1	5	0	-3	0	-3	0	-5	0	0	-3	1.69
	fullface	0	0	1	1	-1	-2	0	0	-3	0	2	0	-6	1	0	-2	1.19
Time-Offset	x-ray	0	0	1	–	0	3	–	-2	-3	-1	-3	1	-5	2	-1	-3	1.79
	fullface	1	–	0	–	0	-0	-4	0	-5	0	0	0	-6	-2	-1	-2	1.50
Transition/[illegible]	x-ray	0	–	0	0	-2	-1	-2	-3	-2	-6	0	–	-5	-8	-2	-1	2.29
	fullface	6	0	-2	3	0	-1	-1	1	0	-8	2	1	-5	-9	-1	-2	2.63
Place	x-ray	2	2	0	5	21	13	3	-1	-2	4	1	-31	13	4	5	13	7.50
	fullface	3	9	2	3	11	27	-4	0	0	-9	-3	-2	3	-1	4	-1	5.13
Tongue Part	x-ray	-7	–	1	–	-5	-11	-3	-6	-1	11	–	-10	8	3	3	6	5.77
	fullface	2	1	0	6	3	-3	-9	-4	-2	1	1	–	1	2	-5	0	2.67
[illegible]	x-ray	1	–	0	1	1	1	-2	3	0	1	0	–	2	-2	-3	–	1.31
	fullface	-1	1	-2	-7	-1	0	1	0	0	-7	-1	–	-2	-1	-6	8	2.53
Tongue [illegible]	x-ray	4	–	1	-1	2	0	-2	3	-1	3	0	-1	0	1	3	–	1.57
	fullface	-1	–	0	0	3	0	0	4	2	-1	1	–	-1	0	2	–	1.15

Table 7. Continued. Judgment Discrepancies for "Moose".

		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Interjudge $\bar{x}$
Time Onset	x-ray	0	–	2	0	-1	2	–	1	0	0	-1	0	1	-1	-1	0	0.71
	fullface	0	–	-1	0	-2	0	–	1	0	0	0	0	0	0	-1	0	0.36
Time Nucleus	x-ray	-1	–	-1	2	2	1	2	2	-2	-2	0	0	1	-1	1	0	1.20
	fullface	-1	-3	0	3	3	0	0	1	-1	0	0	0	0	0	0	0	0.75
Time Offset	x-ray	–	–	0	0	1	-1	–	1	0	-2	0	0	1	1	–	0	0.58
	fullface	0	–	0	–	0	-2	–	2	-1	1	0	1	0	-2	1	0	0.77
Transition Speed	x-ray	0	–	0	-1	-1	0	1	–	0	–	-1	1	–	–	2	0	0.64
	fullface	1	-3	2	0	0	0	-2	-2	1	0	0	1	1	0	0	0	0.81
Place	x-ray	-3	–	-1	-1	12	-12	-8	-2	-12	-9	0	0	0	-2	0	-1	4.20
	fullface	12	2	3	1	-6	–	-8	-13	-4	-10	-3	0	-2	-3	-4	-8	5.27
Tongue Root	x-ray	-1	–	1	-2	5	7	-5	-6	-4	-5	0	0	0	7	–	-1	3.14
	fullface	-5	1	–	1	0	7	-5	-9	1	0	-3	-5	8	4	1	1	3.07
Tongue Shape	x-ray	-2	–	-1	-2	-6	1	9	-2	0	-7	-1	0	-2	2	0	2	2.47
	fullface	2	0	-1	1	-8	-1	-2	-8	-1	0	-2	-1	0	-3	0	-2	2.00
Tongue [illegible]	x-ray	-1	–	-2	0	2	-1	-3	-1	0	0	-2	-2	2	2	-1	0	1.27
	fullface	-1	–	1	-3	0	-1	-1	1	1	0	0	-1	-1	4	0	–	1.07

APPENDIX D

Table 8. Intrajudge Discrepancies (in Scale Points) Between the Mean X-ray Judgment and Individual Full Face Judgments.

		Time-Onset		Time-Nucleus		Time-Offset		Transition Speed		Place		Tongue Part		Tongue Shape		Tongue Elevation	
		1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face
Cake	A	NR	1.00	1.00	1.00	1.16	1.16	0.56	0.44	2.31	3.31	4.03	1.03	0.50	0.50	0.50	0.50
	B	3.00	3.00	0.00	0.00	NR	1.16	2.44	2.44	0.69	3.69	0.03	5.03	1.50	1.50	2.50	3.50
	C	1.00	2.00	0.00	0.00	0.84	1.16	0.44	1.44	5.31	5.31	2.97	0.97	1.50	1.50	0.50	1.50
	D	2.00	2.00	0.00	1.00	NR	0.16	2.44	NR	5.31	7.31	2.97	2.97	1.50	1.50	1.50	0.50
	E	2.00	2.00	0.00	1.00	0.84	0.84	2.44	0.56	0.69	2.31	2.03	1.03	1.50	1.50	0.50	0.50
	F	0.00	1.00	1.00	1.00	1.16	0.16	14.56	1.44	4.69	2.31	1.03	NR	2.50	2.50	0.50	2.50
	G	1.00	2.00	1.00	3.00	NR	1.84	1.44	2.44	6.69	1.31	3.03	3.03	0.50	0.50	1.50	0.50
	H	NR	3.00	1.00	1.00	1.16	0.84	2.44	1.44	1.31	5.69	2.03	2.03	0.50	0.50	0.50	0.50
	J	2.00	1.00	0.00	2.00	0.16	0.84	0.44	1.44	0.31	1.69	2.03	3.03	0.50	1.50	0.50	1.50
	K	0.00	0.00	0.00	0.00	0.16	0.16	0.44	0.44	4.69	5.69	0.03	4.03	0.50	1.50	NR	0.50
	L	2.00	2.00	0.00	0.00	0.16	0.16	2.44	0.44	0.31	0.31	NR	3.97	1.50	1.50	1.50	1.50
	M	0.00	1.00	0.00	0.00	0.16	0.16	1.44	0.44	0.31	5.69	5.97	2.97	0.50	0.50	0.50	0.50
	N	2.00	0.00	0.00	0.00	1.16	0.16	0.44	0.44	1.31	0.31	2.97	0.03	0.50	0.50	0.50	0.50
	O	1.00	0.00	0.00	0.00	0.16	0.84	0.56	0.44	9.31	1.69	4.97	5.97	0.50	1.50	0.50	0.50
	P	1.00	1.00	0.00	0.00	1.16	0.16	1.44	0.56	3.31	3.69	5.97	2.03	0.50	0.50	0.50	0.50
	Q	1.00	0.00	0.00	0.00	0.16	0.16	1.44	0.44	0.31	1.31	1.03	2.97	NR	NR	0.50	NR
x-ray X̄		4.00		4.00		3.84		4.44		31.69		7.03		3.50		4.50	
X̄ discrepancy		1.29	1.31	0.25	0.63	0.60	0.68	2.21	0.99	2.93	3.23	2.74	2.74	0.91	1.23	0.83	1.03
Lamb	A	2.06	1.06	1.84	1.84	NR	1.28	2.02	10.98	2.03	26.03	NR	NR	NR	NR	2.41	NR
	B	3.06	2.06	1.84	2.84	0.28	1.72	14.98	4.02	26.03	17.03	6.53	2.53	0.78	0.22	1.59	0.59
	C	0.94	3.06	1.84	0.84	0.72	0.72	13.98	0.98	23.03	22.03	NR	NR	0.22	0.78	0.41	2.41
	D	1.06	2.06	0.16	1.84	NR	0.72	1.02	0.98	7.97	27.03	0.53	8.47	4.22	1.78	1.41	2.41
	E	1.94	1.94	2.16	2.16	0.28	1.72	1.98	1.02	28.03	26.03	10.53	9.53	1.22	1.22	1.59	0.59
	F	0.94	0.06	1.16	0.16	0.72	1.28	2.02	2.02	1.03	25.03	7.47	6.53	1.22	1.22	1.59	1.41
	G	NR	1.94	0.16	2.16	NR	2.28	12.98	14.98	14.03	8.03	6.47	3.47	0.78	0.78	0.59	0.59
	H	2.06	2.06	0.84	2.84	2.28	2.28	11.98	3.02	22.03	18.03	6.47	4.47	NR	0.22	1.41	1.59
	J	1.06	1.06	0.16	0.16	0.28	1.28	1.02	10.98	0.97	NR	4.47	5.47	0.78	0.78	1.59	2.41
	K	1.06	0.06	0.16	0.16	0.28	0.28	0.02	1.02	1.97	27.03	4.47	NR	2.78	2.78	2.59	1.59
	L	1.94	2.06	0.16	1.84	0.28	2.28	0.98	10.98	27.03	25.03	3.47	6.47	1.22	1.78	0.59	0.41
	M	2.06	0.06	0.16	0.16	0.28	0.28	0.02	11.98	4.03	25.03	NR	NR	0.78	0.78	1.41	0.41
	N	1.94	1.94	2.16	2.16	2.28	1.72	1.98	0.02	1.03	30.03	2.54	NR	0.22	0.78	3.59	1.59
	O	0.94	0.06	0.16	0.16	1.28	0.28	0.98	1.02	7.97	27.03	1.54	NR	0.78	0.78	2.59	0.59
	P	0.94	0.94	1.16	0.16	0.28	1.28	0.98	3.02	3.97	1.03	2.47	7.47	7.22	5.22	0.41	0.41
	Q	0.94	1.06	0.16	0.84	0.72	1.28	0.98	2.02	27.03	8.97	NR	2.47	0.78	NR	2.41	NR
x-ray X̄		4.06		3.84		4.28		5.02		31.03		9.47		4.78		3.41	
X̄ discrepancy		1.53	1.34	0.89	1.27	0.77	1.29	4.24	5.00	12.39	20.89	4.74	5.69	1.64	1.79	1.64	1.21

Table 8. Continued.

		Time-Onset		Time-Nucleus		Time-Offset		Transition speed		Place		Tongue part		Tongue shape.		Tongue elevation	
		1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face	1st session full face	2nd session full face
Turtle	A	0.34	1.34	0.03	0.03	0.78	0.22	3.41	3.41	4.20	1.20	4.41	4.41	0.93	0.07	1.16	1.16
	B	0.34	0.34	0.97	0.03	NR	0.22	1.41	3.41	1.80	0.20	10.59	3.41	1.93	2.07	2.16	3.16
	C	1.66	1.66	0.97	0.03	1.78	1.22	4.41	5.41	4.20	1.20	3.41	0.41	2.07	1.07	0.16	0.16
	D	1.66	0.66	1.03	1.97	1.78	0.78	5.41	5.41	3.80	1.80	1.59	0.41	2.07	2.07	3.16	3.16
	E	1.66	1.66	0.03	0.97	1.78	1.78	8.59	5.41	2.20	5.20	4.41	4.41	0.07	1.93	1.16	0.16
	F	2.66	1.66	1.03	1.03	1.78	0.78	8.59	9.59	5.20	1.80	3.41	3.41	4.93	1.93	2.16	2.16
	G	0.66	0.66	NR	0.03	2.22	1.22	4.41	2.59	3.20	4.20	5.41	5.41	1.07	0.07	1.16	1.16
	H	2.34	0.34	0.97	0.03	1.22	0.22	NR	9.59	3.20	1.20	0.59	3.41	0.93	1.07	0.16	3.16
	J	2.66	2.34	0.03	1.97	0.22	0.22	7.59	3.41	3.20	5.20	3.59	3.41	0.07	2.07	1.16	2.16
	K	0.34	0.34	0.03	0.03	0.22	0.22	4.41	3.41	6.20	3.20	7.41	0.41	1.07	1.07	0.84	0.84
	L	1.66	2.34	0.03	0.03	1.78	0.22	5.41	3.41	1.20	1.20	3.41	1.59	0.07	2.07	1.16	0.16
	M	1.66	0.34	0.03	0.03	1.78	0.22	3.41	3.59	0.80	4.20	0.41	0.59	0.07	0.93	1.16	1.16
	N	2.66	0.34	1.03	0.03	0.22	0.22	6.41	1.59	2.20	5.20	2.59	4.41	5.93	1.07	0.16	0.84
	O	1.66	0.34	0.03	0.03	2.22	2.22	1.59	2.59	0.20	6.20	3.41	1.41	0.93	1.07	1.16	2.16
	P	1.34	0.34	1.97	0.03	1.78	0.78	4.41	2.59	4.20	NR	0.59	3.41	1.93	0.07	1.16	2.16
	Q	1.66	0.66	2.03	1.03	1.78	0.78	5.41	4.41	1.20	2.20	NR	4.41	6.93	7.93	0.16	NR
X-my X̄		3.66		4.03		3.78		7.41		35.20		9.41		4.07		5.16	
X̄ durqn.		1.56	0.96	0.62	0.46	1.42	0.71	4.99	4.63	2.98	2.96	3.68	2.81	1.56	1.66	1.14	1.58
Thumb	A	2.69	0.32	1.81	0.81	2.16	0.16	10.19	11.19	7.80	5.80	NR	NR	2.57	NR	1.57	1.57
	B	2.69	1.32	NR	0.18	NR	1.16	4.81	3.81	8.80	8.80	6.20	NR	0.43	NR	2.43	NR
	C	0.32	1.32	NR	0.18	0.84	0.84	1.81	0.81	2.80	1.80	NR	6.80	0.43	0.43	1.57	0.43
	D	0.32	1.69	0.18	1.18	NR	0.84	12.19	1.81	6.80	6.80	NR	11.80	0.43	1.43	1.57	2.57
	E	2.32	1.69	2.18	1.18	1.84	1.84	0.81	0.81	8.80	6.80	NR	10.80	0.57	1.57	0.57	1.57
	F	1.32	1.32	NR	0.81	0.16	0.84	3.81	2.81	18.20	40.20	9.80	3.20	2.57	1.43	2.57	1.57
	G	0.69	NR	NR	2.18	NR	2.16	4.81	0.81	2.20	3.20	7.80	NR	0.43	NR	2.43	NR
	H	2.69	0.69	1.81	0.18	2.16	1.16	10.19	9.19	7.80	7.80	4.20	NR	NR	NR	1.57	NR
	J	0.32	0.32	2.18	0.18	1.84	2.16	12.19	9.19	42.20	NR	NR	1.80	0.57	0.57	2.57	1.57
	K	0.32	0.32	0.18	0.18	0.16	0.16	3.81	2.81	6.80	6.80	NR	NR	2.57	2.57	1.57	2.57
	L	2.32	2.32	0.18	2.18	1.84	1.84	13.19	13.19	6.20	7.80	NR	1.80	0.57	0.57	0.43	1.43
	M	1.69	0.32	0.18	0.18	NR	0.16	2.81	11.19	5.80	5.80	NR	NR	NR	2.43	NR	1.57
	N	3.32	2.32	1.18	2.18	2.84	1.84	0.19	0.81	6.80	9.80	NR	NR	1.57	1.57	0.57	1.57
	O	0.69	0.32	0.18	0.18	0.34	0.16	2.81	2.81	6.80	8.80	NR	NR	NR	0.57	NR	2.43
	P	0.32	0.32	NR	0.18	0.84	1.16	1.81	2.81	NR	8.80	NR	NR	1.57	1.57	1.57	1.57
	Q	1.32	1.32	1.18	1.18	0.84	0.84	1.81	1.81	5.80	5.80	NR	NR	0.57	0.57	0.43	0.43
X-my X̄		3.69		3.81		4.16		6.81		10.80		12.80		4.57		3.57	
X̄ disagmu		1.46	1.06	1.03	0.83	1.36	1.08	5.45	4.74	9.61	8.98	7.00	6.03	1.14	1.27	1.53	1.60

Table 8. Continued.

		Time-Onset		Time-Nucleus		Time-Offset		Transition Speed		Place		Tongue Part		Tongue Shape		Tongue Elevation	
		1st pass full face	2nd pass full face	1st pass full face	2nd pass full face	1st pass full face	2nd pass full face	1st pass full face	2nd pass full face	1st pass full face	2nd pass full face	1st pass full face	2nd pass full face	1st pass full face	2nd pass full face	1st pass full face	2nd pass full face
House	A	1.22	0.22	1.62	1.62	1.00	NR	0.46	0.54	26.44	25.44	NR	NR	NR	NR	2.97	1.97
	B	1.22	1.22	NR	2.62	1.00	3.00	3.46	3.46	11.44	23.44	8.88	NR	2.07	NR	1.97	NR
	C	0.22	0.22	0.38	1.38	1.00	1.00	1.54	1.54	22.44	24.44	NR	NR	0.07	1.93	2.03	1.97
	D	2.22	1.22	2.62	2.62	NR	2.00	2.54	1.54	27.44	23.44	NR	3.12	0.93	0.07	2.97	1.97
	E	NR	0.22	0.38	0.38	1.00	0.00	0.54	1.54	24.44	27.56	6.88	7.88	0.93	1.07	0.03	1.97
	F	0.78	0.22	2.38	0.62	2.00	1.00	6.46	0.54	33.44	30.44	10.12	6.12	2.93	1.93	1.97	1.97
	G	NR	0.78	0.62	2.38	NR	2.00	1.46	0.46	25.44	22.44	NR	5.88	0.93	0.93	1.03	1.03
	H	0.22	2.22	1.62	2.62	1.00	3.00	0.54	1.54	26.44	25.44	NR	NR	5.07	NR	1.97	NR
	J	0.78	1.22	2.38	1.62	1.00	2.00	1.46	1.54	26.44	24.44	NR	8.12	0.93	0.93	1.97	1.97
	K	2.78	0.78	1.62	0.62	1.00	1.00	2.46	0.46	[illegible]	26.44	NR	10.12	2.93	2.93	1.97	0.97
	L	0.22	0.78	0.38	0.38	0.00	0.00	0.54	0.46	27.44	26.44	NR	NR	0.93	0.93	1.97	1.03
	M	0.78	NR	0.38	0.38	0.00	0.00	0.46	1.46	25.44	23.44	NR	NR	NR	1.07	NR	1.97
	N	1.78	0.78	0.62	0.38	1.00	0.00	0.46	0.46	27.44	27.44	NR	NR	NR	2.93	NR	1.97
	O	1.78	0.22	0.63	0.38	1.00	1.00	0.46	0.54	27.44	22.44	NR	NR	NR	0.93	NR	1.03
	P	1.78	1.78	0.38	0.38	1.00	0.00	0.46	2.46	26.44	27.44	10.12	1.12	1.93	1.93	0.03	1.97
	Q	1.78	0.78	1.38	0.38	1.00	0.00	0.46	0.46	26.44	25.44	NR	NR	0.93	0.93	1.03	1.03
x-ray X̄		3.22		3.62		4.00		10.54		35.44		12.12		4.93		3.97	
X̄ display		1.26	0.84	1.16	1.17	0.93	1.07	1.48	1.19	25.56	25.33	9.00	6.05	1.71	1.62	1.69	1.63
Seal	A	2.59	1.59	2.50	2.50	1.78	NR	6.12	0.88	5.31	2.69	3.72	0.72	0.01	1.99	0.35	0.65
	B	2.59	3.41	2.50	2.50	1.78	2.78	2.88	3.12	4.69	8.31	2.72	1.72	1.01	2.99	1.65	NR
	C	1.41	0.59	0.50	1.50	0.78	0.22	0.88	0.88	8.69	2.69	1.28	6.72	1.01	1.01	0.35	1.35
	D	1.59	1.59	0.50	1.50	NR	1.22	0.12	1.88	1.69	5.69	2.72	2.28	1.99	1.99	2.35	0.65
	E	0.59	1.59	0.50	1.50	0.78	1.78	0.88	1.88	1.69	0.69	3.72	2.72	1.01	0.99	1.35	2.35
	F	1.59	1.41	1.50	0.50	1.22	1.22	0.88	1.12	7.31	1.69	1.28	3.72	0.99	1.01	2.35	2.35
	G	NR	0.41	0.50	1.50	NR	1.22	0.12	1.12	7.31	1.31	6.72	3.72	0.99	0.01	1.35	0.35
	H	0.59	2.41	1.50	0.50	0.78	0.22	0.88	NR	7.31	5.31	3.28	2.72	0.99	1.01	3.35	2.35
	J	0.41	0.59	0.50	0.50	0.22	0.22	1.12	0.12	0.31	1.31	3.72	3.72	0.01	0.99	0.35	2.35
	K	0.41	0.41	0.50	0.50	0.22	0.22	0.12	0.88	3.31	5.31	6.72	4.72	1.99	1.99	0.35	0.35
	L	2.41	0.59	0.50	0.50	1.22	0.22	1.12	0.12	5.31	1.69	2.72	2.28	0.99	0.99	2.35	0.65
	M	0.41	0.41	0.50	0.50	0.22	0.22	0.12	0.88	0.69	1.31	1.28	1.28	0.01	0.99	1.35	0.35
	N	0.59	1.41	0.50	0.50	0.78	0.22	1.88	0.88	7.31	0.69	5.72	2.28	1.99	0.01	2.35	1.35
	O	2.41	0.59	1.50	0.50	1.22	0.78	0.12	0.12	5.69	1.31	9.28	0.72	1.99	1.99	0.65	0.65
	P	0.59	2.41	0.50	1.50	0.22	1.22	1.12	1.12	1.69	1.31	1.72	2.72	0.99	0.01	1.35	0.35
	Q	1.41	0.41	0.50	0.50	0.22	0.22	0.12	0.12	1.69	4.69	2.72	3.72	1.01	2.01	1.35	NR
x-ray X̄		3.59		3.50		3.78		3.88		31.31		8.72		3.99		5.35	
X̄ display		1.31	1.24	0.94	1.06	0.82	0.80	1.16	1.01	4.38	2.28	3.71	2.40	1.06	1.62	1.45	1.15

Table 8. Continued.

		Time - Onset		Time - Nucleus		Time - Offset		Transition speed		Place		Tongue part		Tongue shape		Tongue elevation	
		Intersession fullface	Intrasession fullface	Intersession fullface	Intrasession fullface	Intersession fullface	Intrasession fullface	Intersession fullface	Intrasession fullface	Intersession fullface	Intrasession fullface	Intersession fullface	Intrasession fullface	Intersession fullface	Intrasession fullface	Intersession fullface	Intrasession fullface
Glass	A	1.72	1.72	2.34	2.34	3.16	2.16	0.80	6.80	3.69	2.31	4.35	2.35	0.03	0.97	2.25	1.25
	B	2.72	2.72	2.34	2.34	NR	3.16	2.80	2.80	8.69	0.31	5.35	4.35	1.97	0.97	0.75	NR
	C	1.28	0.28	0.34	0.66	0.84	0.84	1.80	0.21	3.69	1.69	6.35	6.35	1.03	0.97	0.75	0.75
	D	2.72	0.28	2.34	1.34	NR	1.84	0.21	2.80	1.69	1.31	3.35	2.65	7.03	0.03	1.75	1.75
	E	1.72	1.72	0.34	1.34	1.84	1.84	1.21	1.21	2.69	2.31	5.35	2.35	2.03	1.03	1.75	1.25
	F	0.72	0.72	1.66	0.34	0.84	0.84	0.80	0.21	8.69	23.31	3.35	6.35	1.97	1.97	0.75	0.25
	G	NR	NR	1.34	1.34	1.84	2.16	1.80	0.80	1.69	5.69	2.65	6.35	0.97	0.03	0.25	0.25
	H	2.72	2.72	1.34	1.34	2.16	2.16	1.21	0.21	0.69	0.69	0.65	3.35	1.03	1.03	1.75	2.25
	J	0.28	0.28	3.66	0.66	2.84	2.16	0.80	0.80	1.69	0.31	2.35	4.35	0.03	0.03	1.75	0.25
	K	1.28	0.28	1.34	1.34	2.16	2.16	1.80	6.21	3.31	5.69	2.35	1.35	6.03	0.97	2.25	1.25
	L	0.28	0.72	0.66	2.66	1.84	1.84	0.80	2.80	0.31	2.69	7.35	6.35	0.97	1.97	0.25	1.25
	M	0.28	0.28	0.66	0.66	0.16	0.16	0.80	1.80	7.31	5.31	NR	3.65	NR	0.03	NR	0.25
	N	3.28	2.72	3.66	2.34	2.84	3.16	2.80	2.21	9.31	12.31	8.65	9.65	1.03	0.97	0.25	0.75
	O	1.72	0.28	0.34	0.66	0.16	2.16	9.80	0.80	1.69	2.69	1.35	0.65	0.97	1.97	2.25	2.25
	P	1.28	1.28	1.66	1.66	1.16	2.16	0.21	1.21	0.69	3.31	0.65	4.35	6.03	0.03	0.75	1.25
	Q	2.28	0.72	2.66	0.66	1.84	0.16	1.80	0.21	2.31	1.31	6.35	3.65	0.03	8.03	0.25	NR
x-ray X̄		3.72		3.34		4.16		10.21		31.69		8.35		3.97		3.75	
X̄ disagreement		1.62	1.14	1.67	1.36	1.62	1.81	1.84	1.94	4.01	4.45	4.03	4.26	2.08	1.31	1.18	1.11
Moose	A	0.06	0.06	0.19	1.19	0.16	0.16	0.23	1.23	1.83	10.17	6.44	1.44	0.46	2.46	0.58	1.58
	B	2.06	NR	2.81	0.19	NR	1.16	3.23	0.23	14.83	16.83	2.44	3.44	2.54	2.54	0.58	NR
	C	0.94	0.06	0.19	0.19	0.16	0.16	1.77	0.23	9.17	6.17	4.56	NR	1.46	0.46	1.58	0.58
	D	2.06	2.06	2.19	0.81	NR	0.16	1.77	1.77	3.17	2.17	4.56	3.56	2.54	1.54	2.43	0.58
	E	0.06	2.06	1.19	1.81	0.84	0.84	0.77	0.77	10.83	4.83	1.56	1.56	7.46	0.54	2.43	2.43
	F	1.06	1.06	1.19	1.19	1.16	0.84	1.23	1.23	3.17	NR	6.44	13.44	0.54	1.54	0.43	0.58
	G	NR	1.06	0.19	0.19	NR	0.16	1.23	0.77	11.83	3.83	5.44	0.44	0.46	1.54	1.43	0.43
	H	0.06	0.94	0.19	0.81	0.16	2.16	0.23	1.77	0.83	10.17	6.44	2.56	6.46	1.54	0.58	0.43
	J	0.06	0.06	0.19	1.19	0.16	0.84	0.77	0.23	13.83	9.83	0.56	0.44	0.46	0.54	0.58	0.43
	K	0.06	0.06	0.19	0.19	0.16	1.16	0.23	0.23	7.83	2.17	3.56	3.56	1.54	1.54	0.43	0.43
	L	0.06	0.06	0.19	0.19	0.16	0.16	0.23	0.23	3.83	0.83	0.56	3.56	0.54	2.54	1.43	1.43
	M	0.06	0.06	0.19	0.19	0.16	1.16	0.23	1.23	7.83	7.83	5.44	0.44	0.46	0.54	1.43	0.43
	N	0.06	0.06	0.19	0.19	0.16	0.16	0.77	0.23	3.83	1.83	3.56	4.44	2.54	2.54	0.43	1.43
	O	0.06	0.06	0.19	0.19	0.16	1.84	0.23	0.23	3.83	0.83	4.56	0.56	2.54	0.46	3.43	0.58
	P	0.94	0.06	0.19	0.19	0.16	1.16	0.23	0.23	14.83	10.83	2.44	3.44	0.54	0.54	0.43	0.43
	Q	0.06	0.06	0.19	0.19	0.16	0.16	0.23	0.23	10.83	2.83	1.56	0.56	1.46	0.54	1.43	NR
x-ray X̄		4.06		4.19		3.24		10.77		19.17		5.56		3.54		2.58	
X̄ disagreement		0.51	0.52	0.60	0.55	0.24	0.77	0.84	0.68	7.65	6.08	3.76	2.90	2.00	1.34	1.22	0.84