

## ■ Relationships of Speech-Related and Nonspeech Variables to Speech Intelligibility of Children with Palatal and Lip Anomalies

## ■ Liens entre les variables orales et non orales et l'intelligibilité de la parole des enfants ayant des anomalies aux lèvres et palatales

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### Abstract

This investigation aimed to identify variables that predict intelligibility ratings for children with cleft lip and/or palate. Speech-related variables under investigation were: (a) phonological deviation average (PDA), (b) mean length of response (MLR), (c) resonance, and (d) phonation. Nonspeech variables were: (a) age, (b) gender, (c) cleft type, and (d) hearing status. Data were collected from 50 children (32 boys; 18 girls), ages 3-5 years, with cleft lip and/or palate (8 cleft lip; 15 cleft palate; 27 both). Speech intelligibility, resonance and phonation were rated by four trained listeners. The speech-related variables that contributed significantly to the prediction of speaker intelligibility ratings were PDA, MLR and hypernasality. Hearing status and anomaly type were predictive nonspeech variables. The results underline the importance of including phonological analysis in the speech assessment of children with cleft lip and/or palate.

### Abrégé

Cette recherche visait à identifier les variables qui prédisent les cotes d'intelligibilité des enfants ayant un bec-de-lièvre ou une fente palatine. Les variables orales prises en considération dans la recherche étaient : a) la moyenne de déviance phonologique (MDP), b) la durée moyenne de la réponse (DMR), c) la résonance et d) la phonation. Les variables non orales étaient : a) l'âge, b) le genre, c) le type de fente et d) l'état de l'ouïe. Des données ont été recueillies auprès de 50 enfants (32 garçons et 18 filles), âgés de 3 à 5 ans, avec un bec-de-lièvre ou une fente palatine (8 becs-de-lièvre, 15 fentes palatines et 27 ayant les deux). L'intelligibilité de la parole, la résonance et la phonation ont été évaluées par quatre auditeurs qualifiés. Les variables orales qui ont contribué de façon considérable à la prévision des cotes d'intelligibilité des locuteurs sont la MDP, la DMR et la rhinolalie ouverte. L'état de l'ouïe et le genre d'anomalie sont les variables non orales qui aident à prévoir les cotes. Les résultats ont démontré l'importance d'inclure une analyse phonologique à l'évaluation de la parole des enfants avec un bec-de-lièvre ou une fente palatine.

**Key words:** cleft palate and lip, intelligibility, nonspeech variables, and speech-related variables

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Clefts of the lip and/or hard and soft palate are among the most common congenital malformations (Hanson & Murray, 1990). More than one quarter million individuals worldwide were born with a clefting anomaly since 1950 (Centers for Disease Control and Prevention, 2006). Clefting anomalies often result in speech problems, which, in turn, make it difficult for listeners to understand the speaker (Bzoch, 2004; D'Antonio & Scherer, 1995; Estrem & Broen, 1989; Hardin-Jones & Jones, 2005; Hegde, 2007; Morris, 2004; Witzel, 1995). Fricatives, affricates, and oral plosives often are omitted or replaced, and, in many instances, hypernasality or unusual distortions occur, resulting in speech that is unintelligible (D'Antonio & Scherer, 1995; Grunwell, 1996; Trost-Cardamone, 1999; Witzel, 1990).

When analyzing speech characteristics of children with a clefting anomaly, the most common conclusion has been that most of the speech difficulties in this population can be attributed to structural and physiological deviations, particularly velopharyngeal inadequacy (Powers, Dunn, & Erikson, 1990). However, the linguistic investigation of phonological patterns and non-cleft related errors in children with clefts is a relatively recent phenomenon (Chapman, 1993; Chapman & Hardin, 1992; Grunwell, 1993; Hodge & Gotzke, 2007; Hodson, Chin, Redmond, & Simpson, 1983; Lynch, Fox, & Brookshire, 1983).

Grunwell (1993) stressed the importance of detailed phonetic and phonological analyses in all children with intelligibility difficulties, with or without cleft lip and palate. Comprehensive phonetic and phonological evaluations enable the speech-language pathologist to design more effective treatment programs for children with clefts (Grunwell & Dive, 1988). The speech patterns of children with cleft palate can be unique and are not easily transcribed using the standard International Phonetic Alphabet (Grunwell, 1975; Riski, 1994; Trost, 1981). A set of specific diacritic markers has therefore been developed (extIPA; Ball, Esling, & Dickson, 1995). The intelligibility of speakers with cleft lip and palate can be influenced by many variables, including articulation, nasal air emissions, resonance, voice, stress, accent, intonation and rate and fluency of speech (Hodge & Gotzke, 2007; Witzel, 1990). Measurements of understandability are influenced by both the speaker's actual productions and the listener's categorical perception of sounds.

Peterson-Falzone, Hardin-Jones, and Karnell (2001) pointed out that phonological process analysis indicates patterns of deviations, but not etiologies. Although compensatory substitutions are usually described by phonetic (articulatory and acoustic) analysis rather than by phonological analysis, research involving children with clefts (e.g., Hodson et al., 1983) has demonstrated that there are consistent patterns in the children's vocalizations, phonetic inventories and phonological deviations. Further exploration of phonological deviations may provide a better understanding of compensatory articulation, intelligibility and speech sound patterns for this population.

Whitehall and Chau (2004) listed a number of factors, including misarticulated speech and atypical resonance that contribute to reduced speech intelligibility in children with cleft palate. Many children with cleft palate experience difficulty with velopharyngeal incompetence (VPI) in speech. A common consequence of VPI is weak pressure consonant production (Kummer & Lee, 1996). The resulting reduced intra-oral air pressure impacts the production of oral consonants such as stops and fricatives (Whitehill & Chau, 2004).

Although a number of studies have investigated phonological abilities of children without physical anomalies (e.g., Hodson & Paden, 1981; Porter & Hodson, 2001; Hodson, 2007), relatively few have explored the phonological systems of children with cleft lip and palate. Typically, researchers have contrasted the speech patterns of cleft and non-cleft populations (e.g., Chapman, 1993). Most of these studies have been limited by relatively small numbers of participants (Hodson et al., 1983; Lynch et al., 1983; Powers, et al., 1990).

Non-speech variables have also been shown to influence the intelligibility of children with cleft lip and/or palate. Kummer (2008) noted that nasal emission caused an overall reduction in air pressure and resulted in shortened utterance length and choppy speech. Another non-speech characteristic pertains to the type of clefting anomaly. Children with less involved sequelae (e.g., cleft lip only) typically have fewer speech difficulties. Finally, middle ear dysfunction and conductive hearing losses have been widely reported for children born with cleft lip and/or palate (Paradise, 1975; Paradise, Bluestone, & Felder, 1969). The negative impact of persistent middle ear infections and conductive hearing loss on language and speech development has been well documented for children with and without clefting anomalies (Bess & Gravel, 2006; Cole & Flexer, 2007; Kummer, 2008).

Travis (1931) and Van Riper (1939) emphasized that although speech is produced in the speaker's vocal tract, the perception and categorization occurs in the ears and the brain of the listener. Moll (1964) argued that the acceptability of one's speech depends on the listeners' perceptions.

Listeners can provide a direct, noninvasive, and unintrusive evaluation of speaking characteristics in both clinical and research practice. Shriberg and Kwiatkowski (1982a,b) noted that listeners were able to reliably determine intelligibility, resonance, and phonation in continuous speech samples (Karling, Larson, Leanderson, Galyas, & deSerpa-Leitas, 1993; Moller & Starr, 1984; VanDemark, Hardin-Jones, O'Gara, Logemann, & Chapman, 1993). Cordes (1994) argued that, although the reliability of observational data may sometimes be questionable, direct behavior observation methods can provide important and relevant data about speech and language behaviors. Word identification tasks have been reported to be more appropriate than interval-rating scales for determining intelligibility (Schiavetti, 1992; Whitehill, 2002). Listener

scales for rating the intelligibility of young children with varying phonological abilities, however, have been found to have a strong correlation with the “standard” measure of speech, percentage of words identified correctly (Gordon-Brannan & Hodson, 2000).

Perceptual judgments are a key component in speech evaluation (Moller & Star, 1984). Although instrumental procedures such as nasopharyngoscopy and videofluoroscopy are useful for evaluating the movements and patterns of the velopharyngeal structures, they do not measure the degree of speech dysfunction. The listeners are essential in assessing aspects of speech production such as intelligibility and hypernasality (Karling, Larson, Leanderson, Galyas, & deSerpa-Leitas, 1993). Research with various clinical populations has shown that experienced and naïve listeners judge speech similarly, but experienced ones generally understand slightly more of the speech of clinical populations (Bridges, 1991; Keuning, Wieneke, & Dejonckere, 1999; Starr, Moller, Dawson, Graham, & Skarr, 1984; VanDemark et al., 1993).

The purpose of this investigation was to identify variables that predicted listener ratings of intelligibility for children born with cleft lip and/or cleft palate. The research questions were:

Question 1: Do speech-related variables predict children’s intelligibility? Specifically, do measures of resonance, phonation, mean length of response, and phonological deviations predict intelligibility in continuous speech samples obtained from children born with cleft palate and/or lip?

Question 2: Do nonspeech variables predict children’s intelligibility? Specifically, do anomaly type, hearing status, age, and gender predict intelligibility in continuous speech samples obtained from children born with cleft palate and/or lip?

Question 3: What phonological deviations are most common for children born with cleft palate and/or lip?

## Method

### Participants

Fifty children with palatal and/or lip anomalies between the ages of 3:0 (years:months) and 4:11 (chronological age mean 3:11) were tested. Thirty-two were boys, and 18 were girls. All of the children resided in the province of Saskatchewan. Sixteen of the children were of First Nations descent, and 34 were Caucasian. Five of the children spoke two languages in the home (3 Cree, 1 Dene and 1 Ukrainian); the remainder spoke only English.

The children in this study presented with the following clefting anomalies: Eight children had a cleft lip only, 15 had a cleft palate only and 27 children had both cleft lip and palate. For the children born with a cleft palate anomaly (n=42), the average age at palatal surgery was 1:3 (range of 0:7 to 1:11). Two of the children with cleft palate anomalies had not yet had palatal surgery at the time of the study. The timing of surgery was not included

as a predictor variable in the final analyses because of this restricted range of timing of surgery.

Hearing was within normal limits for 31 of the children. Three children had mild hearing loss, 12 had moderate hearing loss and 4 had severe hearing loss on the days of testing.

### Procedures

Caregivers of potential participants were approached during an appointment at a cleft-lip and palate clinic in either Saskatoon or Regina. Most children were tested on the same day as the clinic. If immediate assessment was not possible, an appointment was arranged with the caregiver, and testing was completed on a separate day.

### Speech Samples

The *Assessment of Phonological Processes-Revised* (APP-R; Hodson 1986) was administered by the first author, followed by recording a continuous-speech sample. The APP-R responses and the continuous-speech samples were recorded onto TDK IEC1/Type 1 audio cassettes (TDK Corp., Uniondale, NY 11556) via a Crown Sound Grabber microphone (Crown Audio, Elkhart, IN 46517) connected to a Marantz (PMD 222; Marantz Canada Inc., Markham, Ontario L3R 5B1) audiotape recorder. Each participant’s speech deviations for the APP-R were transcribed online by the examiner. Delayed imitation was used whenever a child did not name the stimulus item spontaneously.

The first author and a speech-language pathology graduate student skilled in phonetic transcription independently transcribed each child’s speech deviations from the APP-R samples on the audiotapes. Both the first author and the student were familiar with identification of compensatory articulation errors that are characteristic for cleft palate speakers. When discrepancies between the two transcribers occurred, audiotape segments were replayed until consensus was reached. Verified transcriptions for the APP-R were scored for occurrences of phonological deviations (e.g., consonant sequence reduction, velar deficiencies) and analyzed to derive phonological deviation percentage-of-occurrence scores for each child.

For the continuous speech samples, the children and the examiner played with a Tupperware block set, which had small toys hidden inside each block. Children were encouraged to talk about the toys as they opened the blocks. Open-ended questions and requests (e.g., “Tell me about when you saw that?” or “What does that do?”) were used when a child was reluctant to talk.

A sample of 50 responses was selected excluding the first minute of audiotape to calculate each child’s MLR (Bloodstein, 1979). The MLR measure was calculated rather than the mean length of utterance because of difficulties that often occur in identifying morphemes for children with highly unintelligible speech. The number of words (50) was divided by the number of responses to obtain a number representing the MLR. This continuous speech sample was also used for the listener rating procedures.

**Table 1**  
Intercorrelation Matrix for Listener Ratings of Speech-Related Variables.

Measure	Listener	Listeners			
		A	B	C	D
Speech Intelligibility	A	1.00			
	B	.86**	1.00		
	C	.90**	.89**	1.00	
	D	.88**	.93**	.89**	1.00
Resonance	A	1.00			
	B	.65**	1.00		
	C	.78**	.56**	1.00	
	D	.70**	.64**	.66**	1.00
Phonation	A	1.00			
	B	.43**	1.00		
	C	.54**	.51**	1.00	
	D	.48**	.45**	.61**	1.00

Note: Each correlation represents 2 listeners. Each measure represents a rating on a 1- to 7- scale. \*\*  $p < .01$

### Listener Ratings

Four speech-language pathologists (one male, three females) served as listeners. All had experience with young children with reduced intelligibility, but their experience with children with cleft lip and/or palate varied. All passed a 20 dB audiometric screening at the octave frequencies 250 Hz through 8000 Hz (ANSI, 1997). Their ages ranged from 26 to 40 years (chronological age mean of 29:10).

The 50 speech samples were randomly ordered and rerecorded onto a master listening tape (Maxell UR IEC 1 Normal audio cassettes; Maxell Canada, Concord, ON Canada, L4K 4V3), using two Marantz audiotape recorders of the same model (PMD 222). In addition, 10 of the speech samples were selected randomly and repeated on the end of the listening tape to provide samples for evaluating intrajudge reliability. Thus, the listening tapes contained a total of 60 speech samples. The listeners were not told they were rating 10 speakers a second time. The tapes were presented to the listeners via a Sharp audiotape recorder (RD – 685 AV; Sharp Electronics of Canada Ltd.).

Prior to the actual rating, a 2-hour training session was conducted in which the listeners rated 20 representative speech samples not included in the study. During this training session, listeners were allowed to discuss ratings and ask questions, but during the actual data collection procedures, all ratings were made independently. Prior to listening to the continuous speech samples, the listeners were shown the materials used to elicit the sample to familiarize them with the context. Instructions for rating the speakers were provided orally and in written form.

A 7-point scale was used for rating speech intelligibility. Point 1 was defined as “easily understood speech,” 4 as the “midpoint,” and 7 as “extremely difficult to understand.” Thirty samples were rated in two-hour sessions on two consecutive days.

One week later, two additional two-hour listening sessions on consecutive days were conducted. The listeners

rated each speaker on the speech-related variables, resonance (hypernasality), and phonation (hoarseness) using a similar 7-point scale. The same procedures were employed as for the intelligibility judgment task. Listeners rated 30 samples at a sitting on two consecutive days. Scores for the four listeners were averaged to obtain each child’s overall intelligibility mean as well as means for the resonance and phonation variables.

### Hearing

Hearing of participants who passed the audiometric screening procedure at the Cleft Lip and Palate Clinic appointment was judged as being within normal limits and given a coding of 1. A mild hearing loss was defined as a Pure Tone Average (PTA) from 27 to 40 dB HL, moderate as a PTA of 41 to 55 dB HL, and severe as above 56 dB HL. These were coded 2, 3, and 4 respectively.

### Interjudge reliability

Interjudge reliability for phonetic transcriptions between the first author and the student research assistant was assessed by using a point-by-point agreement index as follows: A (agreement for consonant transcriptions) divided by A + D (number of consonants where there were disagreements initially) times 100 = percentage of agreement. The percentage of agreement value was 85.07%.

For the four listeners, zero order correlations for pairs of listeners’ ratings ranged from .86 to .93 for intelligibility, from .56 to .78 for resonance and .43 to .61 for phonation. (See Table 1 for the intercorrelation matrix for listener ratings). The correlations were strongest for intelligibility, followed by resonance and phonation. The correlations for resonance and phonation were moderate.

### Intrajudge reliability

To assess the intrajudge reliability of listener ratings, 10 continuous-speech samples were rated twice for all three measures. For speaker intelligibility, the listeners’ ratings were the same or within one point of each other for 95%



**Table 2**  
Means and Standard Deviations for Age and Speech-Related Variables (N = 50)

Measure	Mean	Standard Deviation
Age in Months	47.54	6.47
Intelligibility	4.47	1.89
MLR	4.19	1.49
Phonological Deviation Average (%)	38.04	21.69
Resonance	3.26	1.62
Phonation	2.64	1.22

**Table 3**  
Zero Order Correlations of Speech-Related Variables and Intelligibility

	Intelligibility	Resonance	Phonation	PDA
Resonance	.59			
Phonation	.24	.19		
PDA	.82	.56	.19	
MLR	-.79	-.27	-.23	-.64

**Table 4**  
Zero Order Correlations of Nonspeech Variables and Intelligibility

	Intelligibility	Age in Months	Gender <sup>a</sup>	Hearing
Age in Months	.04			
Gender <sup>a</sup>	-.03	-.01		
Hearing	.34	-.09	-.08	
Anomaly	.32	.45	-.22	.56

<sup>a</sup>Gender was coded 1 = boy and 2 = girl.

(38/40) of their responses and within two points for the remaining 5% (2/40) responses. When rating phonation, 87.5% (35/40) of the listeners' responses were the same or within one point. Ratings were within two points for 5% (2/40) of the responses, within three points for 5% (2/40), and within five points for 2.5% (1/40) of the responses. For 72.5% (29/40) of the resonance ratings, the listeners' ratings were the same or within one point. For an additional 22.5% (9/40) of the responses, their ratings were within two points. Two responses (5%) had discrepancies of three and four points.

## Results

### Data Analysis

#### Speech-Related Variables

The means and standard deviations of the speech-related and nonspeech variables are reported in Table 2. The speech-related and nonspeech variables are discussed in the following sections.

The first question addressed was "Do speech-related variables predict children's intelligibility?" Intelligibility was regressed on the speech variables (resonance, phonation, MLR, and PDA) using a stepwise regression procedure in SPSS 14.0 (SPSS Inc.). In a stepwise regression, variables compete for entry. The variable accounting for the greatest amount of variance enters first, followed by the

variable accounting for the next greatest variance, until no additional variables are significant. Three variables were significant and entered in the following order: PDA [ $F(1, 48) = 101.41, p < .001, b = .07, R^2 = .68$ ], MLR [ $F(1, 47) = 29.05, p < .001, b = -.57, R^2 = .12$ ], and resonance [ $F(1, 46) = 11.76, p < .001, b = .29, R^2 = .04$ ]. This means that the more deviant the PDA and resonance ratings, the lower the intelligibility ratings. The longer the MLR, the higher the intelligibility ratings. The zero order correlations among these variables are shown in Table 3.

#### Nonspeech Variables

The second question addressed was "Do non-speech variables predict children's intelligibility?" Again, stepwise regression was conducted. Intelligibility was regressed on hearing status, anomaly type, gender, and age in months. Two variables were significant and entered in the following order: hearing status [ $F(1, 48) = 6.28, p < .05, b = .59, R^2 = .12$ ] and anomaly type [ $F(1, 47) = 5.40, p < .05, b = .75, R^2 = .09$ ]. Poorer hearing and more severe involvement of clefting were associated with poorer intelligibility ratings. The zero order correlations among these variables are shown in Table 4.

#### Phonological Deviations

The third question, "What phonological deviations are most common for children born with cleft palate and/or lip anomalies?" was answered by further evaluation of the phonological deviations to determine their frequency of occurrence in the speech samples. Table 5 provides the summary information.

The most common omissions in the samples of the children in this study occurred for consonant sequences. The most frequently occurring consonant category deficiencies involved stridents, liquids and velars. Consonant category deficiencies were coded when the phonemes in the category were lacking either because of omission or because of a substitution of a consonant from a different category (e.g., /t/ for /s/ in the strident category). One relatively uncommon deviation, prevocalic singleton omissions, was noted, in the speech samples of 26 children.

## Discussion

Many children born with clefting anomalies produce speech that is not easily understood. Identification of individual variables associated with decreased speech intelligibility is integral to a complete understanding of the nature of the intelligibility difficulties experienced by these children. A main contribution of the present study is the addition of the descriptive phonological measures to

**Table 5**  
Phonological Deviations Evidenced by Children Born with Lip and/or Palatal Anomalies (N = 50).

Phonological Deviations	Number of Children	Percentage-Of-Occurrence Mean
Omissions		
Consonant Sequences	47	56
Postvocalic Singletons	38	22
Prevocalic Singletons	26	7
Syllables	17	3
<i>Consonant Category Deficiencies</i>		
Stridents	50	68
Liquid /r/	47	76
Liquid /l/	46	66
Velars	42	43
Glides	36	27
Nasals	30	12

the speech and non-speech characteristics associated with clefting. Each of these predictor variables studied merits further discussion.

### Speech-Related Variables

#### Resonance

The literature has consistently reported resonance abnormalities, particularly hypernasality, in the speech of children with clefting anomalies (Kummer, 2008). Hypernasality can co-occur with obligatory articulation errors such as nasal emissions and reduced pressure consonants (Kummer, 2008; Witzel, 1995). Of all the predictor variables in this study, resonance (hypernasality) performed the poorest, explaining only 4% of the variance in intelligibility. The results from this study are preliminary and limited, and we do not wish to suggest that resonance does not contribute to the overall picture. It was interesting to note, however, that hypernasal resonance was only minimally predictive of intelligibility for the children in this study.

#### Mean Length of Response

In the present study, longer MLRs correlated with better intelligibility. We suspect that children with longer MLRs were simply more advanced in their overall speech and language skills. Utterance length predicted 12% of the variance in intelligibility, suggesting that although it was a better predictor than resonance, its value as a predictor was not strong.

#### Phonological Deviations

The PDA derived from the APP-R provided the percentage-of-occurrence for 10 major phonological deviations. Although this assessment instrument was not designed to measure speech intelligibility the PDA does correlate with intelligibility measures and the severity of a speech disorder (Hodson, 2007). The results from this study indicated the PDA was the strongest predictor of speech intelligibility for children with clefting anomalies,

accounting for 68% of the variance in intelligibility.

It has been argued that the speech errors of children with cleft lip and palate are strictly related to structural conditions and are therefore phonetic (i.e., non-linguistic) in nature (D'Antonio & Scherer, 1995; Golding-Kushner, 2001). The results of the present study demonstrate that the phonological deviations shown by the children in this study were similar to those of children with highly unintelligible speech described by Hodson and Paden (1981). Over half of the children in the current study demonstrated omissions of consonants in clusters and also consonant category deficiencies involving liquids, stridents and velars. The types of phonological deviations contributing to unintelligibility appear to be similar regardless of etiology. A major difference between results of these two studies was that over half of the children with cleft palate in this study omitted prevocalic singleton consonants, whereas none of the children in the Hodson and Paden (1981) study demonstrated such a pattern.

### Non-Speech Variables

#### Hearing

Nearly 40% (19/50) of the participants presented some hearing loss. Hearing loss accounted for 12% of the variability in intelligibility. Children with more severe hearing loss received lower ratings for intelligibility. Churchill, Hodson, Jones and Novak (1988) compared phonological deviation occurrences of 15 children (between the ages of 3:7 and 5:11) with documented histories of otitis media to the performance of 15 children who had speech sound disorders but no otitis media. The major difference between the two groups pertained to more cluster reductions (46% vs. 27%) and deficiencies involving stridents in the otitis media group (59% vs. 12%). Interestingly, these two deviations were also prevalent in the participants of the present study. The phonological profiles of the children in this study were not unlike other children with histories of otitis media.

#### Cleft type

The results of this study support the premise that children with less involved clefts have fewer speech difficulties. The children with more involved clefts (i.e., both cleft lip and palate) received lower intelligibility ratings by the listeners, with the severity of anomaly accounting for 9% of the variance in intelligibility.

### Conclusions

In summary, several speech and non-speech characteristics, including resonance, MLR, PDA scores, hearing acuity, and severity of clefting anomaly significantly predicted intelligibility ratings for children with clefting anomalies. The strongest predictor was the phonological measure, PDA (accounting for 68% of the variance). This finding should encourage researchers to investigate

phonological systems of children with clefts, preferably with more recently published assessment tools (e.g., Hodson, 2004). In future research, it would also be desirable to undertake a more detailed assessment of the children's speech intelligibility, using the procedures developed by Hodge and Gotzke (2007).

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