

NASAL ASSIMILATION AND SUBSTITUTION IN STANDARD INDONESIAN: EVIDENCE FROM LOANWORDS PRODUCTION TASK*

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This paper investigates nasal assimilation and substitution in Standard Indonesian (SI). In SI, the verbal prefix /məN-/ alternates in its shape at the prefix-root boundary when it is combined with root-initial obstruents. This study examines loanword roots borrowed from Arabic, Portuguese, Dutch and English. Using a speech production task, this investigation finds patterns of variation which are conditioned by inter- and intra-speaker differences, and place of articulation. This study proposes to model the patterns of variation in Noisy Harmonic Grammar (NHG; Coetzee and Kawahara 2013, Coetzee and Pater 2011).

Keywords: *nasal assimilation, nasal substitution, optimality theory.*

Makalah ini mengkaji asimilasi dan substitusi konsonan nasal di Bahasa Indonesia. Dalam Bahasa Indonesia, awalan kata kerja /məN-/ berubah bentuknya ketika awalan ini digabung dengan kata dasar yang dimulai dengan bunyi obstruen. Kajian ini meneliti kata pinjaman dari bahasa Arab, Portugis, Belanda dan Inggris. Melalui eksperimen produksi ujaran, penelitian ini menemukan pola variasi yang dikondisikan oleh perbedaan antar penutur dan perbedaan yang terjadi pada penutur yang sama, dan juga oleh posisi artikulasi. Makalah ini bermaksud untuk merumuskan pola variasi yang ditemukan ke dalam teori Noisy Harmonic Grammar (NHG; Coetzee and Kawahara 2013, Coetzee and Pater 2011).

Kata kunci: *asimilasi konsonan nasal, substitusi konsonan nasal, optimality theory.*

INTRODUCTION

Nasal assimilation and substitution occur when the nasal prefix /məN-/ is combined with root-initial obstruents. These phonological alternations are widely known among scholars working on Indonesian phonology. Most studies of nasal assimilation and substitution in Indonesian have examined native Malay/Indonesian roots. However, none of the current studies of Indonesian phonology has given further observation to the patterns of nasal assimilation and substitution in loanword roots which behave differently from the native roots. Sneddon (1996) reported that nasal assimilation or substitution may alternately occur with voiceless-initial stops [p, t, k] in loanword roots. These patterns are exemplified in (1):

- (1) (a) Native: /məN+pilih/ məmilih ‘to choose’
 (b) Dutch/English: /məN+paten+kan/ məmpatenkan¹ ~ məmatenkan ‘to patent’

For the Indonesian native root, the underlying representation /məN+pilih/ becomes [məmilih] in (1a), while the underlying representation /məN+paten+kan/ in the Dutch/English (D/E) root may surface as [məmpatenkan] or [məmatenkan] in (1b).

This study investigates these phonological patterns in Standard Indonesian (SI), the national and official language of Indonesia. This study examines nasal assimilation and

substitution in loanword roots borrowed from Arabic, Portuguese, Dutch and English. Using a speech production task, this investigation finds patterns of variation which are conditioned by inter- and intra-speaker differences, and place of articulation. This study proposes to model the patterns of variation in Noisy Harmonic Grammar (NHG; Coetzee and Kawahara 2013, Coetzee and Pater 2011).

Nasal Prefix in Native Roots

In previous studies of nasal assimilation and substitution in Indonesian, Lapoliwa (1981), Pater (1999, 2001), Sneddon (1996), among others, reported that a nasal in the coda position of the verbal prefix /məN-/ alternates in its representation at the prefix-root boundary. Following the majority of previous works on Indonesian, I use N- in /məN-/ to represent placeless nasal. In this section, I will present the pattern of nasal prefix (henceforth: məN-prefix) in SI. First of all, a description of native roots that begin with liquids, glides, and nasals are presented in (2):

(2) Root-initial liquids, glides, and nasals:		
(a) /məN+lamar/	məlamar	‘to propose’
(b) /məN+rusak/	mərusak	‘to destroy’
(c) /məN+jakin+i/	məjakini	‘to believe’
(d) /məN+wabah/	məwabah	‘to be epidemic’
(e) /məN+makan/	məmakan	‘to eat’
(f) /məN+nilai/	mənilai	‘to grade’
(g) /məN+nyanyi/	mənyanyi	‘to sing’
(h) /məN+nggakur/	mənggakur	‘to do nothing’

Deletion of placeless nasal (N) occurs in root-initial liquids, glides, and nasals. The məN-prefix is realized as [mə-]. The next data set in (3) displays the realization of məN-prefix when it is combined with root-initial vowels:

(3) Root-initial vowels:		
(a) /məN+aŋkat/	məŋaŋkat	‘to lift’
(b) /məN+obat+i/	məŋobati	‘to medicate’
(c) /məN+undang/	məŋundang	‘to invite’
(d) /məN+ekor/	məŋekor	‘to follow’
(e) /məN+isi/	məŋisi	‘to fill’

In root-initial vowels, placeless nasal (N) is realized as nasal velar [ŋ]. For root-initial voiced obstruents, the patterns are described in (4).

(4) Root-initial voiced obstruent:		
(a) /məN+bəli/	məmbəli	‘to buy’
(b) /məN+guntiŋ/	məŋguntiŋ	‘to cut with scissors’
(c) /məN+dapat/	məndapat	‘to get’
(d) /məN+dzawab/	məndzawap	‘to answer’

The phonological patterns in (4) are commonly known as nasal assimilation. The placeless nasal (N) assimilates to the root-initial voiced obstruent forming homorganic clusters.

The following data shows mənN-prefix when it is conditioned by root-initial voiceless consonants.

- (5) Root-initial voiceless obstruent:
- | | | |
|------------------|-----------------------|----------------------|
| (a) /mənN+pilih/ | məmilih | ‘to choose, to vote’ |
| (b) /mənN+tulis/ | mənulis | ‘to write’ |
| (c) /mənN+kasih/ | məŋasih | ‘to give’ |
| (d) /mənN+sapu | məŋapu | ‘to sweep’ |
| (e) /mənN+teari/ | məŋteari ² | ‘to seek’ |

Following serial rule ordering approach, Ikranagara (1980) proposed that the placeless nasal (N) assimilates to the root-initial voiceless obstruent which then forms homorganic clusters. This process is followed by deletion of the root-initial obstruent. For example, the placeless nasal in /mənN+pilih/ assimilates to [m] so that it realizes as [məmpilih], followed by deletion of [p]. Consequently, the final realization is [məmilih]. In the more recent studies, Pater (2001) and Zuraw (2010) termed these two phonological processes as nasal substitution.

Nasal Prefix in Loanword Roots

The patterns of nasal assimilation and substitution in loanword roots behave differently from native roots. There is a pattern of variation when the mənN-prefix encounters root-initial voiceless stops. It may be realized into two forms as exemplified in (6).

- (6) mənN-prefix + loanword roots
- | | | |
|----------------------|--------------------------|--------------------|
| (a) /mənN+paten+kan/ | məmpatenkan ~ məmatenkan | ‘to patent’ (E) |
| (b) /mənN+taat+i/ | məntaʔati ~ mənaʔati | ‘to obey’ (A) |
| (c) /mənN+komando/ | məŋomando ~ məŋkomando | ‘to command’ (E/D) |

The data in (6) show that nasal assimilation and substitution may occur when the mənN-prefix is combined with root-initial voiceless stops. Nasal assimilation happens as in [məmpatenkan] in which placeless nasal (N) assimilates to bilabial nasal forming homorganic consonant clusters [mp], while nasal substitution occurs in [məmatenkan] in which placeless nasal (N) becomes bilabial nasal [m], and the voiceless stop [p] is deleted.

We have seen so far that the nasal assimilation and substitution show different patterns between native and loanword roots. There are patterns of variation found in the loanwords, while such patterns are never allowed to occur in the native words.

Goals of the Present Study

This current study aims to observe the patterns of variation of nasal substitution and assimilation produced by SI native speakers in a speech production task. This study focuses on the patterns of use of mənN-prefix when it is combined with root initial voiceless stops [p, t, k] in SI loanwords.

This study also suggests to model the patterns of variation found in a speech production task in Noisy Harmonic Grammar, developed by Coetzee and Kawahara (2013), and Coetzee and Pater (2011).

PRODUCTION TASK

This section elaborates procedure, participants, and results of this study.

Subjects

There are eight subjects involved in this production task. They are five female and three male native speakers of Indonesian. They are educated speakers of Indonesian who live in Ithaca, New York, as Cornell University graduate students, their spouses, or faculty. Their age ranges between twenty five until forty five years old.

Procedure

There are three phases in this production task. They are pre-training, training, and testing phase. In the pre-training phase, subjects listen to six passive sentences recorded by a male native speaker. These pre-training sentences are passive voice with DI-prefix. These sentences are in random order. The verbs used in the passive sentences are native roots. They are root-initial glides, liquids and vowels which do not undergo nasal assimilation or substitution. A female native speaker is also recorded. This female speaker responds in active voice with mənN-prefix for each passive sentence uttered by the male speaker. The purpose of the pre-training phase is to provide subjects with examples on how to respond to the test sentences later in the testing phase. In the training phase, there are eighteen training sentences recorded by the same male speaker. These training sentences are also in passive voice. The order is also randomized. Similar to the pre-training sentences, the verbs are also from the native roots. They are also root-initial glides, liquids and vowels which do not undergo nasal assimilation or substitution. The subjects listen to these eighteen passive sentences, and they have to respond in active sentence with mənN-prefix. The purpose of this task is to ensure that the subjects understand the instructions and examples provided in the pre-training sentences. The task is discontinued if the subject produced a maximum of three incorrect responses out of eighteen training sentences.

In the testing phase, there are thirty loanwords recorded by the same male speaker. The loanword roots are from Arabic, Portuguese, Dutch and English. These testing sentences are also in passive voice. The order is also randomized. These loanwords begin with [p-, t-, k-] (labial, alveolar, and velar respectively) initials. The subjects listen to these thirty passive sentences; and they are instructed to produce active sentences based on the passive sentences provided in this task. The placeless nasal in mənN-prefix and the root-initial stops in the loanwords are expected to either undergo nasal assimilation or substitution, as exemplified in (6). Each word is embedded in two different test sentences. Therefore, there are a total of sixty test sentences in this task.

The examples in (7) and (8) display the loanword *komando* (D/E) ‘to command’ embedded in two different test sentences. The test items are in italics.

- (7) Subjects listen to:
gerakan kerjabakti minggu ini *dikomando* oleh Pak RT
move-AN community.service week this DI-command by Mr. RT³
‘that community service was led by the head of RT (neighborhood association).’

Expected response:

Pak RT *məŋomando/məŋkomando* gerakan kerjabakti minggu ini.
‘Mr. RT led the community service this week.’

- (8) Subjects listen to:
 gerak jalan itu *dikomando* oleh Dimas.
 move walk that DI-command by Dimas
 ‘the hike was led by Dimas.’

Expected response:
 Dimas *məŋomando/məŋkomando* gerak jalan itu.
 ‘Dimas led the hike.’

The topics and sentences are composed in a formal style. To avoid response bias toward nasal assimilation or substitution, twenty distracters are placed in between three test sentences. The distracters are liquids, glides and vowel initials from native roots which never undergo nasal assimilation or substitution. Now let us turn to the results from the production task.

Results

The results from production task show three patterns of variations. They are inter-speaker variation and intra-speaker variation, and variation that is conditioned by place of articulation. First, let us discuss the inter-speaker variation found in this study.

Inter-speaker variation

The inter-speaker variation is presented in Figure 1. The total distribution of nasal assimilation and substitution altogether constitutes 100%. They are pooled across places of articulation, i.e. labial [p], alveolar [t], and velar [k]. I only present the distribution of nasal substitution in Figure 1. Therefore, any percentage that is not shown in Figure 1 is the percentage of nasal assimilation.

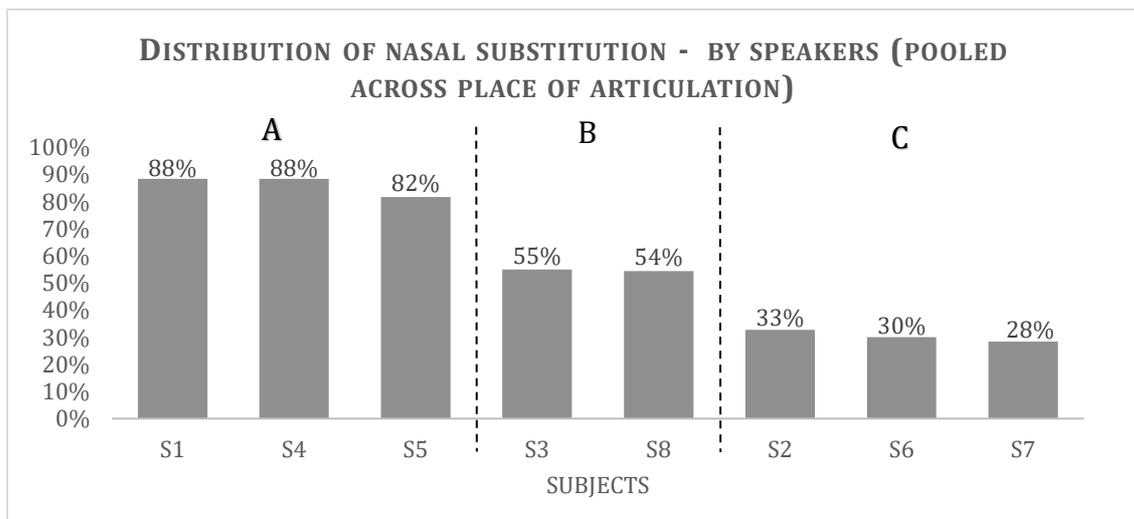


Figure 1. Distribution of Nasal Substitution

The horizontal axis in Figure 1 is for the eight subjects in the task (S1, S2, S3, S4, S5, S6, S7, and S8), while the vertical axis is for the distribution percentage. For example, subject 1 (S1)

produced 88% nasal substitution, and 12% nasal assimilation (not shown in the figure). There are three types of speakers. Speakers type A (S1, S4, and S5) produce 82% - 88% nasal substitution, speakers type B (S3 and S8) produce 54% - 55% nasal substitution, and speakers type C (S2, S6, S7) produce 28% - 33% nasal substitution. Divisions of these categories are indicated by vertical dash lines in the Figure 1. I will now present the results that show intra-speaker variation.

Intra-speaker variation

All subjects involved in this task produce intra-speaker variation. The results in Table 1 shows the details of the intra-speaker differences.

Table 1. Intra-speaker Differences

Speaker	Gender	Variation within place of articulation	Percentage
S8	M	8	27%
S5	M	7	23%
S7	F	5	17%
S1	M	5	17%
S4	F	5	17%
S3	F	5	17%
S2	F	2	7%
S6	F	2	7%

The third column of Table 1 shows the numbers of test items produced with variation within the same place of articulation. This variation is produced by the same speaker. For example, S8 produces [məŋkomərsilkan] ‘to commercialize’ in the first test sentence, and [məŋomərsilkan] in the second test sentence. This happens across lexical items. In another lexical item, S8 also produces this kind of variation; he produces [məŋərəmatkan] ‘to make sacred’ in the first test sentence, and [məŋkərəmatkan] in the second test sentence. The percentage in the fourth column tells us the percentage of the variation produced out of a total of 30 test sentences.

Place of Articulation

Besides inter- and intra- speaker differences, the patterns of variation in this study are also conditioned by place of articulation. The distribution of nasal assimilation and substitution are pooled across eight speakers. Figure 2 displays the results.

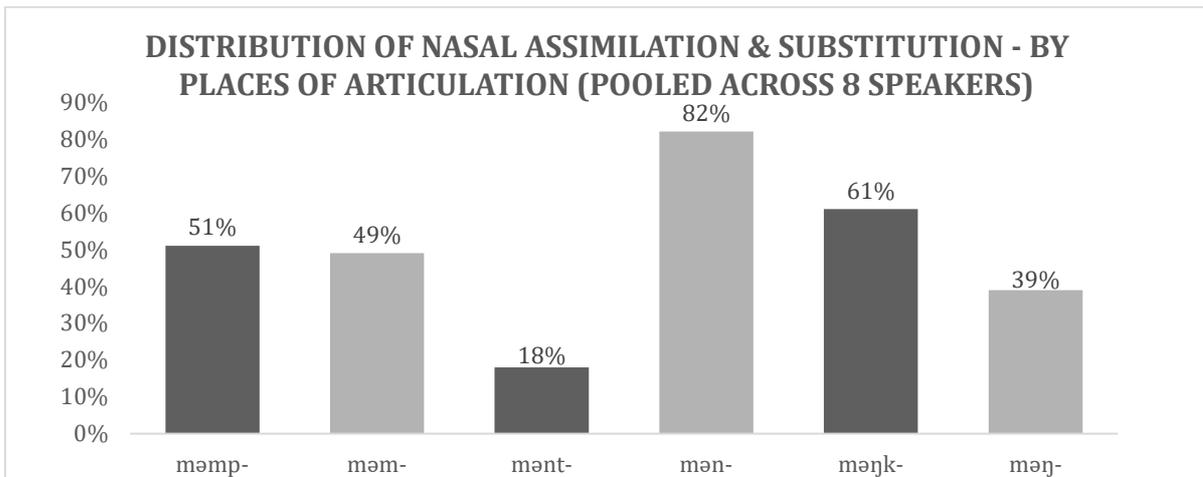


Figure 2. Places of articulation

We can see in Figure 2 that the bilabial (p-initial loanword root) shows almost equal distribution between assimilation [mæmp-] (51%) and substitution [mæm-] (49%). Dental/alveolar (t-initial loanword root) shows lower distribution of assimilation [mænt-] (18%), and higher distribution of substitution [mæn-] (82%). Velar (k-initial loanword root) shows higher distribution of assimilation [mæŋk-] (61%), and lower distribution of substitution [mæŋ-] (39%).

Thus far, we have seen three sources of variation in this study. They are inter- and intra-speaker differences, and place of articulation. The next section provides a formal analysis to account for observed variation found in this study.

PREVIOUS MODEL

The most recent studies of nasal assimilation and substitution in Indonesian are examined within Optimality Theory account (OT; Prince and Smolensky 1993, 2004) by Pater (1999, 2001) and Zuraw (2010). It is therefore important to review what the formal driving forces are behind the nasal assimilation process and to inquire how formal analyses are able to model such variation found so far.

In this section, we focus on modeling of inter-speaker variation. First, OT accounts for SI by Pater and Zuraw are reviewed, then the constraint ranking used by Pater is applied to the results from the production task.

OT account for Indonesian

Pater (1999) used *NT as a high constraint that dominates LINEARITY (LIN) to analyze nasal substitution. He proposed that the [+nasal] segment cannot be immediately followed by a [-voiced, -sonorant] segment, as cited in Zuraw (2010).⁴ This what motivates *NT has higher rank. His analysis is described in (9).

(9) *NT >> LIN

/mæN ₁ +p ₂ ilih/ ‘to choose’	*NT	LIN
→ a. mæm _{1,2} ilih		*
b. mæm ₁ p ₂ ilih	*!	

LIN is violated since the sequence mapping between input and optimal output in (a) is no longer match. This sequence mapping is indicated with numerals (1, 2). The active *NT in losing candidate (b) does not permit nasal-voiceless consonant to occur as the optimal output. This process is generated to other voiceless-initial obstruents [t] and [k]. In his revisited version (2001), Pater reanalyzed the nasal substitution. In this revisited paper, he used a constraint proposed by Itô and Mester (1999), CRISP-EDGE[PRWD], to replace *NT.⁵ He defined this constraint as “no element belonging to a Prosodic Word may be linked to a prosodic category external to that Prosodic Word.” He used this constraint because he found that the NT sequence occurs root-internally in Indonesian.

Pater applied NASALASSIMILATION (NASASSIM) to block any nasal-obstruent sequence that does not have the same place of articulation, following Jun (1995), Padgett (1995), and Boersma (1998). This is applied to both nasal-voiceless and nasal-voiced obstruent. The complete *tableau* from Pater’s investigation is presented in (10).

(10) IDENT[VOICE], NASASSIM >> CRISP-EDGE[PRWD] >> UNIFORM(ITY)⁶

/məN ₁ +p ₂ ilih/ ‘to choose’	IDENT[VOICE]	NASASSIM	CRISP-EDGE[PRWD]	UNIFORM
a. məm ₁ , ₂ ilih				*
b. məm ₁ p ₂ ilih			*!	
c. məŋ ₁ p ₂ ilih		*!		
/məN+bəli/ ‘to buy’ ⁷	IDENT[VOICE]	NASASSIM	CRISP-EDGE[PRWD]	UNIFORM
d. məmbəli			*	
e. məŋbəli		*!		
f. məməli	*!			

In (10), NASASSIM is ranked higher than CRISP-EDGE[PRWD]. We see that NASASSIM is active to block sequence [-ŋp-] in (10c) and [-ŋb-] in [10e) which do not have the same place of articulation. Pater, following Trigo (1991), mentioned that pharyngeal expansion would trigger voicing, whereas pharyngeal constriction is related to nasality. Pater (2001) introduced the use of constraint IDENT[PHAREXP] to block nasal substitution from occurring in voiced-initial obstruents. However, Cohn (1993, and personal communication, August, 2014) argues against this pharyngeal expansion analysis⁸. Before introducing IDENT[PHAREXP], Pater (2001) already schematized IDENT[VOICE] which can be used to block nasal substitution that occurs from the underlying nasal voiced sequence. Therefore, instead of using IDENT[PHAREXP], this paper uses IDENT[VOICE]. In (10f), IDENT[VOICE] is active to block the losing candidate [məməli] from occurring as the optimal output.

In a more recent study, Zuraw (2010) proposed sample ranking for a factorial typology of nasal substitution for some Austronesian languages. She proposed a full ranking argument for Indonesian: *NT >> *[ŋ] *[n, *[m, *ASSOC >> DEP-C. She adopted *NT from Pater (1999). For a nasal constraint family *[ŋ], *[n, and *[m, Zuraw (2010) suggested that a stem must not begin with [ŋ, n, m] segments. *ASSOCIATE (Yip 2002, 2007) is used by Zuraw to penalize any phonological units whose inputs belong to different morphemes. DEP-C is used to block any coda nasal in məN-prefix that is realized in the output that corresponds to the placeless nasal /-N-/ in the underlying representation.

Thus far, we have the constraint ranking argument from Pater and Zuraw's analysis on SI. In the rest of this section, I will apply the constraints we have so far to the data in this study.

OT Account for Standard Indonesian Loanwords

The constraint ranking argument is now applied to the results from SI loanwords production task. Most of the constraints used in this section are based on Pater's suggestion. The main reason for opting Pater's constraint ranking suggestion is because of its ability to account for nasal assimilation and nasal substitution and it works specifically for Indonesian data.

All speakers in the production task show patterns of variation where candidates such as [məŋomərsilkan] and [məŋkomərsilkan] 'to commercialize' are likely to occur in the output. The question now is how OT is then able to handle the variation produced by these speakers, where two possible forms may occur in the optimal output.

In examining lexical variation, Zuraw (2010) found that there are some Tagalog words whose patterns of nasal substitution have not yet been established. This type of word can be realized either in substitution or non-substitution forms. I apply the variation in JI into her suggestion, as displayed in (11).

(11) *Tableau for SI loanwords variation*

/məN+komando/ 'to command'	CRISP-EDGE[PRWD]	UNIFORM
→ a. məŋ _{1,2} omando		//*
→ b. məŋ _{1,k₂} omando	*	//

Following Zuraw (2010), I use jagged line to allow both (11a) and (11b) to surface. Accordingly, the constraint CRISP-EDGE[PRWD] and DEP are variably ranked, rather than categorically ranked. This variability in the constraint ranking shows gradient pattern in the production task results. I suggest that this variability that occurs in the constraint ranking can be further modeled in Noisy Harmonic Grammar with weight scaling, developed by Coetzee and Kawahara (2013).

MODELING VARIATION IN NOISY HARMONIC GRAMMAR

In this section, we return to the pervasive pattern of intra-speaker variation seen in the production task results. As we have observed before, there are three type of speakers found in Figure 1. Type A speakers produce 82-88% nasal substitution form. Type B speakers produce 54-55% nasal substitution form. Type C speakers produce 28-33% nasal substitution form. The rest of this paper is devoted to applying JI production task results for type A speakers into Noisy Harmonic Grammar model which is developed by Coetzee and Kawahara (2013) and Coetzee and Pater (2011).

Before we begin to model JI production data into Noisy Harmonic Grammar framework, I briefly elaborate the Harmonic Grammar itself.

Harmonic Grammar

According to Coetzee and Kawahara (2013), Harmonic Grammar (HG) is a historical predecessor of OT (Goldsmith 1993; Legendre *et al.* 1990)⁹. HG works with weighted constraints rather than ranked constraints. In HG, each constraint is weighted. Arabic numerals

indicate the weight of the constraints. The *tableau* in (12) illustrates how the output [məŋomando] ‘to command’ is evaluated in HG.

(12) $w(\text{NASASSIM}) \gg w(\text{CRISP-EDGE}[\text{PRWD}]) \gg w(\text{UNIFORM}(\text{ITY}))$

/məN ₁ +k ₂ omando/ ‘to command’	15 NASASSIM	10 CRISP- EDGE[PRWD]	5 UNIFORM	H-score
→ a. məŋ _{1,2} omando			-1	-5
b. məŋ _{1,k} omando		-1		-10
c. mən _{1,k} omando	-1			-15

HG provides every constraint with certain weight. UNIFORM is weighted 1, CRISP-EDGE[PRWD] is weighted 5, NASASSIM is weighted 10. Instead of using asterisks, all constraint violations are marked with negative integers (-1). Score in harmony scale (H-score) is calculated by multiplying the constraint weight with the negative integers (-1). A candidate with H-score closest to zero is selected as the optimal output. Coetzee and Kahawara formulated HG as follows:

$$(13) \quad H(\text{cand}) = \sum_{i=1}^n w_i C_i(\text{cand})$$

“Where w_i is the weight of constraint C_i , and $C_i(\text{cand})$ is the number of violations of candidate *cand* in terms of C_i expressed as a negative integer.”

The HG account above does not generate variation. The grammar always maps input to one candidate as the optimal output. This cannot be used to generate variable outputs as we found in JI where candidate (12b) [məŋkomando] is also likely to occur. Noisy HG can generate this variable outputs. Constraint ranking in noisy HG is designed as a continuous scale, rather than a categorical scale as in classic OT. Now let us turn to see how noisy HG analyzes the variation in SI loanwords.

Noisy Harmonic Grammar

Variation analyzed in this section is limited only to the variation from the production task found in Figures 1 and 2. Noisy evaluation in HG creates a room for constraints to accommodate relative ranking between two constraints. This relative ranking may be variable based on one occasion to another occasion as results of variation. Let us first evaluate the results from production task in Figure 1. I will augment the noisy (*nz*) value by scaling the results from this figure. The noisy value is taken from the percentage produced by Type A speakers. We see that the distribution of nasal substitution in Figure 1 ranges from 28-88%. The noisy value scale can be then categorized into 5 scales: -2.5 *nz* for the result between 80-100%, -2 *nz* for the result between 60-79%, -1.5 *nz* for the result between 40-59%, -1 *nz* for the result between 20-39%, -0.5 *nz* for the result between 1-19%. We also need to assign value for 0% result. I assign 0.5 *nz* for 0% result. More restricted candidates receive higher value. The candidate with 0% result is actually the loosing candidate which never occurs as the winning one. The candidate that has more probability to occur receives less noisy value which is represented in negative integers. Thus, the candidates that occur between 80-100% receive -2.5 *nz*, while those that occur between 60-79% receive -2 *nz*, and so forth.

Coetzee and Kawahara updated the new formula by adding the noisy values, as illustrated in (14).

$$(14) \quad H(\text{cand}) = \sum_{i=1}^n (w_i + nz_i) C_i(\text{cand})$$

“where w_i is the weight of constraint C_i , nz_i the noise associated with constraint C_i at this evaluation occasion, and $C_i(\text{cand})$ is the number of violations of candidate cand in terms of C_i expressed as a negative integer.”

To make it clear, I provide the illustration in *tableau* (15). This one case is to calculate the H-score value from S1 from Type A speakers.

$$(15) \quad w(\text{NASASSIM}) \gg w(\text{CRISP-EDGE}[\text{PRWD}]) \gg w(\text{UNIFORM}(\text{ITY}))$$

/mən ₁ +k ₂ omando/ 'to command'	w	nz	w	nz	w	nz	H-score
		15	0.5	10	-0.5	5	
	NASASSIM (15.5)		CRISP-EDGE [PRWD] (9)		UNIFORM (3)		
→ a. mən _{1,2} omando (substitution)					-1		-2.5
→ b. mən _{1,k} omando (assimilation)			-1				-9.5
c. mən_{1,k}omando	-1						-15.5

The weight scale of the constraint and the negative integer (-1) are the same as the one in HG tableau in (12). For S1, the noisy (nz) value for UNIFORM in (15) is obtained from the results of nasal substitution production. The results in Figure 1 show that the production of nasal substitution is 88% which falls into -2.5 nz value. The nasal assimilation forms are then 12% which falls into -0.5 nz value.

The value in parenthesis below each constraint is calculated by adding a weight (w) value to nz value. Now each constraint has its own weight value. Harmonic (H) score value is achieved by multiplying constraint value to the negative value (-1). The bold line indicates the threshold of the candidates that can occur or not occur in the output. For this case, I suggest that the candidates with the H-score value higher than -10 are likely to occur and undergo variation. They are candidates [mən₀omando] in (15a) and [mən_komando] in (15b). The candidates that have the H-score value lower than -10 are never realized in the output. They are candidates [mən_komando] in (15c).

The H-score values indicate the gradient or continuous scale of variation. The grammar, which is represented by the constraint weights, remains the same. The variation, which is represented by the noisy value, is adjustable based on an occasion, in this case intra-speaker variation.

Now we can use Table 2 to calculate H-score values for the rest of type A speakers (S4 and S5), and also speakers belonging to type B and C.

Table 2. H-Score Values for all Speakers

Type	Speakers	Variable output	H-score
A	S1	Nasal substitution	-3
		Nasal assimilation	-9.5
	S4	Nasal substitution	-3
		Nasal assimilation	-9.5
	S5	Nasal substitution	-3
		Nasal assimilation	-9.5
B	S3	Nasal substitution	-3.5
		Nasal assimilation	-8.5
	S8	Nasal substitution	-3.5
		Nasal assimilation	-8.5
C	S2	Nasal substitution	-4
		Nasal assimilation	-8
	S6	Nasal substitution	-4
		Nasal assimilation	-8
	S7	Nasal substitution	-4
		Nasal assimilation	-8

From Table 2, we see that the H-scores of nasal substitution from type A speakers are closer to zero than those of type B speakers. The H-scores of type B speakers are closer to zero than type C speakers. As mentioned above, within the HG framework, the H-score closest to zero is selected as the optimal output. The H-scores in Table 2 show this patterns. Speakers of type A have -3 H-score for nasal substitution, which is the closest one to zero, compared to speakers of type B and C who receive -3.5 and -4 respectively.

For variation that is conditioned by place of articulation, we have seen so far from SI loanwords results in Figure 2. The distribution of nasal substitution that occurs in root-initial alveolars (82%) is higher than that in root-initial bilabials (49%); and the distribution of nasal substitution that occurs in root-initial bilabials is higher than root-initial velars (39%). The final calculation of the H-score value for all places of articulation is described in Table 3.

Table 3. H-score values by Place of Articulation

Place of articulation	Variable output	H-score
Dental/alveolar	Nasal substitution [mən-]	-3
	Nasal assimilation [mənt-]	-9.5
Bilabial	Nasal substitution [məm-]	-3.5
	Nasal assimilation [məmp-]	-8.5
Velar	Nasal substitution [məŋ-]	-4
	Nasal assimilation [məŋk-]	-8

We see that dental/alveolar receives -3 *nz*, which is the closest to zero, followed by bilabial and velar that receive -3.5 and -4 respectively. Zuraw's (2010) proposed nasal substitution hierarchy based on the place effect is [b] > [d] > [g] or bilabial > alveolar > velar respectively. Based on the Tagalog written corpus, she found that [b] has higher rates for substitution than [d] which has higher rates than [g]. If we apply the Tagalog nasal substitution hierarchy to SI loanwords production task results in Figure 2 and H-score calculation in Table 3, we have a different hierarchy [t] > [p] > [k] or alveolar/dental > bilabial > velar respectively.

Thus far, we have seen that the patterns of variation of nasal substitution and assimilation can be modeled using Noisy Harmonic Grammar. Within Noisy HG, all variable outputs are likely to occur as the optimal outputs. This “variability of this optimality” can be achieved by calculating the H-score in the Noisy HG model. To summarize, I provide a conclusion and orientation for further research in the next section.

CONCLUSION

From the production task, we can see that speakers of Indonesian produce patterns of variation in nasal assimilation and substitution when the nasal prefix is combined with loanword roots. The data in this study show that there are three conditions of variation: inter-speaker variation, intra-speaker variation and place of articulation.

When the nasal prefix is combined with loanword roots, two possible outputs may surface. Within Noisy Harmonic Grammar, both outputs are likely to occur as optimal outputs. This “variability of the optimality” can be achieved by calculating the H-score in the NHG model. Antilla (2002), as cited in Coetzee and Kawahara (2013), suggests that sufficient phonological theory must be able to provide an account for “locus of variation” and “degrees of variation”. The evaluation of variation in Indonesian nasal substitution and assimilation within the NHG model provides an example of a promising bridge between the variationist tradition and mainstream generative grammar.

Further research still need to be conducted to see any possibility of mapping grammatical *competence* into the weighted constraint, and mapping *performance* and non-grammatical factors, such as speech style and registers as the multiple sources of variation, into the noisy values.

NOTES

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¹ ‘kan’ is transitive marker.

² No substitution is applied to /tɕ-/initial root but rather the underlying nasal assimilates to the affricate and is realized as the palatal nasal /ɲ/ but the affricate /tɕ/ is not deleted.

³ -AN: nominalizer; DI-: passive marker.

⁴ See Hayes (1999) for a phonetic motivation.

⁵ Other phenomenon in Indonesian (see Cohn and McCharty 1994/1998) supports the crisp-edge idea.

⁶ Instead of LINEARITY, Pater used UNIFORMITY in his revisited paper. This constraints functions similarly.

⁷ In (1999) paper, Pater used placeless nasal /mᴀN-/ in the underlying representation. In (2001) paper, he used /mᴀŋ-/ in the underlying representation. He did not mention any reason for this change. For consistency, I use placeless nasal /mᴀN-/ for the rest of analysis.

⁸ Trigo (1991) argues that in Madurese, the pharyngeal features spread from the voiced and heavy aspirated stops to following vowels are either Advanced Tongue Root or Lowered Larynx. See Cohn (1993) for her detail argument against this analysis.

⁹ A noisy version of OT is known as stochastic OT (Boersma 1997; Boersma & Hayes 2001). Both stochastic OT and noisy HG models are used to account for variable phenomena.

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Appendix
Speech Production Task: mən-
Loanwords in Standard Indonesian

Instruksi:

Anda akan mendengar beberapa kalimat dalam Bahasa Indonesia. Kalimat tersebut adalah kalimat pasif. Tugas anda adalah mengucapkan kalimat aktifnya. Berikut ini merupakan contoh kalimat pasif tersebut dan bagaimana anda nantinya akan mengucapkan kalimat aktif. Setelah si pria mengucapkan kalimat aktif, si wanita akan mengucapkan kalimat pasif setelah bunyi ‘beep’.

Instruction:

You will listen to some sentences in Indonesian. They are passive sentences. Your task is to utter the active sentences. You will listen to some examples of passive sentences and how you will utter the active sentences. After the man utter the active sentences, the woman will utter the passive sentences after you hear 'beep' sound.

Pre-Training:

1. Male (M) : lukisan itu sedang dilihat oleh pengunjung
Female (F) : pengunjung sedang melihat lukisan itu
Male (M) : *that picture is being observed by the visitors*
Female (F) : *the visitors is observing the picture*
2. M : pohon itu telah dirobohkan oleh angin topan
F : angin topan telah merobohkan pohon itu
M : *that tree was collapsed by the hurricane*
F : *the hurricane collapsed the tree*
3. M : orang tua murid boleh diwakili oleh wali murid
F : wali murid boleh mewakili orang tua murid
M : *student's parents may be represented by other guardian*
F : *other guardian may represent student's parents*
4. M : agama nenek moyang tersebut diyakini oleh penduduk setempat
F : penduduk setempat meyakini agama nenek moyang tersebut
M : *the ancestor religion was practised by the local people*
F : *the local people practised their ancestor religion*
5. M : piala itu diincar oleh semua kesebelasan
F : semua kesebelasan mengincar piala itu
M : *that trophy was targeted by all teams*
F : *all teams targeted that trophy*
6. M : Ardi selalu diandalkan oleh atasannya
F : Atasannya selalu mengandalkan Ardi
M : *Ardi is always relied by his supervisor*
F : *the supervisor always relies on Ardi*

Instruksi:

Sekarang silahkan anda mengucapkan kalimat aktif seperti yang diucapkan oleh suara wanita di atas. Silahkan ucapkan suara anda setelah anda mendengar bunyi 'bip'.

Instruction:

Now please say the active sentences like they are uttered by the woman before. Please say your voice after you hear the 'beep' sound.

Training:

1. M : Anjing itu dilepas oleh tuannya
R :
M : *That dog was unleashed by his master*

- R :
2. M : aku diundang oleh Pak Camat
R :
M : *I was invited by the head of district*
R :
3. M : toko itu dirampok oleh kawanan bersenjata
R :
M : *that store was robbed by an armed group of people*
R :
4. M : bajuku sudah diobras oleh tukang jahit
R :
M : *my clothes was sewn by the tailor*
R :
5. M : Ani dirayu oleh Tono
R :
M : *Ani was courted by Tono*
R :
6. M : hantu tersebut sudah dienyahkan oleh mbah dukun
R :
M : *that ghost was casted by the shaman*
R :
7. M : pesan rahasia itu diwasiatkan oleh leluhurnya
R :
M : *that secret message was inherited by the ancestor*
R :
8. M : aku diajak oleh Pak Jarwo
R :
M : *I was invited by Mr. Jarwo*
R :
9. M : pembajakan buku dilarang oleh pemerintah
R :
M : *book piracy was forbidden by government*
R :
10. M : kambing itu diiket oleh Yudi
R :
M : *that goat was tied by Yudi*
R :
11. M : tanah itu diwakafkan oleh Pak Haji
R :
M : *that land was donated by Mr. Haji*
R :
12. M : anak itu diurus oleh neneknya
R :
M : *that kid was taken care by his grandma*

- R :
13. M : tanaman saya dirusak oleh hama wereng
R :
M : *my plant was destroyed by planthoppers*
R :
14. M : uang itu diambil oleh Roni
R :
M : *that money was taken by Roni*
R :
15. M : penjahat itu sudah diringkus oleh polisi
R :
M : *that bad guy was arrested by the police*
R :
16. M : pekerjaan itu diulang lagi oleh Yongki
R :
M : *that job was redone by Yongki*
R :
17. M : bola itu dilempar oleh Ujang
R :
M : *that ball was thrown by Ujang*
R :
18. M : Andi diajarkan oleh Nina berhitung
R :
M : *Andi was taught by Nina how to count*
R :

Test 1:

1. M : perkara tersebut sedang diproses (E) oleh pengadilan
R :
M : *that case is being processed in the court*
R :
2. M : dua gol ditargetkan (E) oleh tim PSSI
R :
M : *two goals were targeted by PSSI team*
R:
3. M : gerakan anti rokok sedang dikampanyekan (D) oleh para artis ibu kota
R :
M : *The anti-smoking action is being campaigned by the artists from capital city*
R:
Distracter : *Andi diwawancarai wartawan*
R : *Andi was interviewed by the journalists*
R :
4. M : peraturan baru itu ditaati (A) oleh masyarakat

- R :
M : *that new rule is obeyed by the people*
R :
5. M : perusahaan tersebut dipailitkan (D) oleh pengadilan karena bangkrut
R :
M : *that company was declared bankrupt by the court*
R :
6. M : tanah kosong itu dikapling (D) oleh pengembang apartemen
R :
M : *that empty land was divided into lots by apartment developer*
R :
Distracter : *Pekerjaan itu diabaikan oleh Suparman*
R : *That task was neglected by Suparman*
R :
7. M : motorku diparkir (D) oleh Adi di halaman depan
R :
M : *my motorcycle was parked by Adi in the front yard*
R :
8. M : kuburan tua itu dikeramatkan (A) oleh penduduk setempat
R :
M : *that old graveyard was made sacred by the local people*
R :
9. M : dia ditakdirkan (A) oleh Tuhan menjadi orang kaya
R :
M : *he was destined by God to be a rich man*
R :
Distracter : *Ular itu dilepaskan oleh Pak Hasan ke habitatnya*
R : *That snake was released by Mr. Hasan to its habitat*
R :
10. M : badak bercula satu dikategorikan (D/E) oleh UNESCO sebagai binatang langka
R :
M : *rhinoceros was categorized by UNESCO as endangered animals*
R :
11. M : merk dagang tersebut telah dipatenkan (D/E) oleh pemerintah
R :
M : *that brand name was patented by the government*
R :
12. M : data tersebut sudah ditabulasi (D/E) oleh Nurul
R :
M : *the data was tabulated by Nurul*
R :
Distracter : *semut itu diinjak gajah*
R : *That ant was trampled by the elephant*

- R :
13. M : luka Dodi sudah diplester (D) oleh Lina
R :
M : *Dodi's wound was plastered by Lina*
R :
14. M : kalimat dalam bahasa asing itu ditafsirkan (A) oleh beberapa ahli
bahasa
R :
M : *the sentences in that foreign language was interpreted by several linguists*
R :
15. M : uang emas itu dikoleksi (D/E) oleh Pak Indra
R :
M : *that gold money is collected by Mr. Indra*
R :
Distracter : *Lubang itu diuruk oleh warga*
R : *That hole was filled up by people*
R :
16. M : musik dangdut dipelopori (D) oleh Rhoma Irama
R :
M : *The dangdut musics was pioneered by Rhoma Irama*
R :
17. M : gerakan kerjabakti minggu ini dikomando (D/E) oleh Pak RT
R :
M : *that community service was led by the head of RT*
R :
18. M : tim lawan telah ditaklukan (A) oleh tim tuan rumah
R :
M : *the opposing team was defeated by the home team*
R :
Distracter : *Rita diejek Tino kemarin*
R : *Rita was ridiculed by Tino yesterday*
R :
19. M : tari-tarian daerah tersebut dikombinasikan (D/E) oleh koreografer itu
R :
M : *those local dances were combined by that choreographer*
R :
20. M : lengan kanannya ditato (E) oleh Bang Toni
R :
M : *his right hand was tatoed by Toni*
R :
21. M : budaya lokal Indonesian telah dipenetrasi (D) oleh budaya asing
R :
M : *the Indonesian local culture has been penetrated by foreign culture*

- R :
Distracter : *Anak putrinya dilamar oleh pedagang kaya*
R : *His daughter was proposed by a rich merchant*
R :
22. M : rumah susun itu dikomersilkan (E) oleh para calo
R :
M : *that flats were commercialized by middle men*
R :
23. M : karyawan tersebut dipensiunkan (D) oleh perusahaan itu
R :
M : *that employee was made to retire by that company*
R :
24. M : kalimat bahasa Inggris itu diterjemahkan (A) oleh Surya
R :
M : *that English sentence was translated by Surya*
R:
Distracter : *Jembatan itu dirancang oleh insinyur ternama tersebut*
R :
M : *The bridge was designed by the prominent engineer*
R :
25. M : lemari itu dipelitur (D) oleh Pak Andi kemaren
R :
M : *that cupboard was polished by Mr. Andi yesterday*
R :
26. M : masalah tersebut akan dikomunikasikan (D) oleh pimpinan sidang
R :
M : *that problem will be communicated by the meeting chair*
R :
27. M : rumah aktivis tersebut sering diteror (E) oleh orang tak dikenal
R :
M : *The activist's house was often terrorized by unkonwn people*
R :
Distracter : *Momen penting tersebut diabadikan oleh fotografer itu*
R :
M : *That picture of important meeting was taken by the photographer*
R :
28. M : ulang tahun Ira dipestakan (Port) oleh ayahnya dengan meriah
R :
M : *Ira's birthday was feted gloriously by her father*
R :
29. M : biaya perjalanan sudah ditotalkan (D) oleh bendahara kantor
R :
M : *the travel cost was summed up by the office treasure*
R :
30. M : pembangunan gapura gang itu dikoordinir (D) oleh Pak RW
R :

- M : the construction work of the alley gateway was led by the head of RW
R :
Distracter :
M : kapal itu akan dilabuhkan oleh nahkoda di Tanjung Priuk
R :
M : that ship was anchored by the captain at Tanjung Priuk
R :

Test 2 (the same words as test 1; embedded different sentences):

1. M : penjualan yang tinggi akan ditargetkan (E) oleh tim marketing
R :
M : the high sale was targeted by the marketing team
R :
2. M : berkas-berkas itu sudah diproses (E) oleh bagian keuangan
R :
M : the files were processed by the finance department
R :
3. M : program parpol sedang dikampanyekan (D) oleh para juru kampanye
R :
M : the program from political parties are being campaigned by the campaigners
R :
Distracter : Persoalan itu sudah diutarakan penduduk
R :
4. M : kebijakan baru itu ditaati (A) oleh seluruh karyawan
R :
M : the new policy was obeyed by all employees
R :
5. M : lahan itu sudah dikapling (D) oleh si pembeli
R :
M : the land was divided into lots by the buyer
R :
6. M : supermarket itu dipailitkan (D) oleh pengadilan
R :
M : that supermarket was declared bankrupt by the court
R :
Distracter : Risma diijinkan ayahnya untuk bermain sepeda
R : Risma has got permission from her father to ride bicycle
R :
7. M : rumah kosong itu dikeramatkan (A) oleh orang-orang situ
R :
M : that empty house is being sacred by the local people
R :
8. M : sepedanya diparkir (D) oleh Joni di depan rumah
R :

- M : *the bicycle was parked by Joni in front of the house*
R :
9. M : kamu ditakdirkan (A) oleh Tuhan untuk menjadi jutawan
R :
M : *you are destined by God to be a millionaire*
R :
Distracter : *Pendidikan gratis sudah lama diwacanakan oleh pemerintah*
R : *Free education has been put into discourse by the government since a long time ago*
R :
10. M : angka-angka itu akan ditabulasi (D/E) oleh Mira
R :
M : *those numbers were tabulated by Mira*
R :
11. M : karya asli Indonesia harus segera dipatenkan (D/E) oleh pemerintah
R :
M : *the original works from Indonesia must be patented soon by the government*
R :
12. M : pelanggaran itu dikategorikan (D/E) oleh polisi sebagai tindak pidana
R :
M : *The violation is categorized as criminal by the police*
R :
Distracter : *Pasien itu diobati oleh dukun*
R : *The patient was treated by the traditional healer*
R :
13. M : tembok itu sudah diplester (D) oleh tukang bangunan
R :
M : *that wall was plastered by the construction worker*
R :
14. M : lirik lagu itu ditafsirkan (A) oleh para penggemar
R :
M : *the song lyrics was interpreted by the fans*
R :
15. M : mobil tua dikoleksi (D/E) oleh Mas Roy
R :
M : *that old car was collected by Roy*
R :
Distracter : *Rambu itu selalu dilanggar oleh pengendara motor*
R : *That sign was always been violated by the motorcycle rider*
R :
16. M : kemajuan bangsa harus dipelopori (D) oleh para pemuda
R :
M : *the progress of the nation should be pioneered by the youth*

- R :
17. M : gerak jalan itu dikomando (D/E) oleh Dimas
R :
M : *that hike was led by Dimas*
R :
18. M : kerbau gila itu ditaklukan (A) oleh Hadi
R :
M : *that mad buffalo was conquered by Hadi*
R :
Distracter : *Kasus korupsi itu diotaki pejabat daerah setempat*
R : *That corruption case was orchestrated by the local government official*
R :
19. M : warna-warna itu dikombinasikan (D/E) oleh Lina
R :
M : *those colors were combined by Lina*
R :
20. M : betis kirinya ditato (E) oleh tukang tato
R :
M : *her left calf was tatoed by the tattooist*
R :
21. M : organisasi tersebut telah dipenetrasi (D) oleh kekuatan asing
R :
M : *that organization was penetrated by an alien power*
R:
Distracter : *Tini sudah dilamar oleh Tono*
R : *Tini was proposed by Tono*
R :
22. M : novel tersebut diterjemahkan (A) oleh beliau
R :
M : *that novel was translated by him*
R :
23. M : banyak pekerja dipensiunkan (D) oleh pabrik itu
R :
M : *many workers were made retired by that factory*
R :
24. M : pembebasan lahan itu dikomersilkan (E) oleh pejabat setempat
R :
M : *the land acquisition was commercialized by the local official*
R :
Distracter : *Kurikulum itu dirancang oleh para ahli pendidikan dasar*
R : *That curriculum was designed by the expert of elementary education*
R :
25. M : kebijakan itu akan dikomunikasikan (D) atasan kepada karyawan
R :

- M* : *That policy will be communicated by the supervisor to the employees*
R :
26. *M* : meja belajarnya dipelitur (D) oleh tukang kayu
R :
M : *The desk was polished by the carpenter*
R :
27. *M* : rumahnya sering diteror (E) hantu perempuan
R :
M : *the house was often terrorized by the female ghost*
R :
Distracter : *Pesta perpisahan ini akan diabadikan oleh pihak sekolah*
R : *The picture of this farewell party will be taken by the school*
R :
28. *M* : pernikahan mereka dipestakan (Port) oleh ayahnya dengan mewah
R :
M : *their wedding will be celebrated by her father with luxury*
R :
29. *M* : uang pembelanjaan akan ditotalkan (D) oleh Pak Jali
R :
M : *the purchasing cost will be summed up by Mr. Jali*
R :
30. *M* : gerakan kebersihan kampung akan dikoordinir (D) oleh Pak Lurah
R :
M : *the village cleaning action will be led by the chief of the village*
R :