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Repetition Reduction Revisited: The Prosody of Repeated Words in Papuan Malay

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Abstract
It has frequently been shown that speakers prosodically reduce repeated words in discourse. This phenomenon has been claimed to facilitate speech recognition and to be language universal. In particular, the relationship between the information value of a word in a discourse context and its prosodic prominence have been shown to correlate. However, a literature review provided in this paper reveals that most evidence comes from English, where prosodic marking of information status often coincides with repetition reduction. The current study investigates to what extent repetition reduction occurs in Papuan Malay, spoken in the western part of the island of New Guinea (Indonesia). The work on Papuan Malay prosody available to date suggests fundamental differences compared to English and other Germanic languages. An acoustic analysis is carried out on repeated words in short stories produced by native Papuan Malay speakers. The results show that upon repetition, words were shortened *and* produced with higher F0. In a subsequent word identification task, it was found that first and second mentions were equally intelligible. Conclusions partially confirm previous work and challenge theories on how the prosody and information value of a word are related.

Keywords
Prosody, repetition reduction, Papuan Malay, production, perception, prominence

1 Introduction

Speakers tend to reduce words prosodically when these are repeated in discourse (e.g., Fowler & Housum, 1987). For example, when a speaker starts mentioning the new car he or she bought, the first production of the word "car" is generally more carefully articulated compared with subsequent productions of the same word. That is, the repeated word's prosody generally shows reduced values for acoustic cues such as F0, duration and intensity. Repetition reduction has also been found in other domains. For example, upon repetitively referring to the same entity, speakers tend to use lexical alternatives that are shorter; for example, "it" instead of "the car" (e.g., Clark &

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Wilkes-Gibbs, 1986) and tend to reduce their co-speech gestures (Hoetjes, Koolen, Goudbeek, Krahmer & Swerts, 2015).

Exactly which information factors drive prosodic reduction has been the topic of various studies. It has been shown that information redundancy (Aylett & Turk, 2004), phonological context (Gahl, Yao & Johnson, 2012), lexical frequency and probability (Jurafsky, Bell, Gregory & Raymond, 2001) all affect the prosodic reduction of words. That is, the more a word is redundant, frequent or probable given a specific context, the more likely the speaker is to reduce this word prosodically. In the case of repetition, a word is more redundant because it has already been mentioned in recent discourse.

These repetition findings are compatible with current theories on prosodic prominence and intonation. For example, Germanic languages like English commonly use pitch accents to highlight new information and deaccent given information (e.g., Ladd, 2008). New information is generally low in redundancy, while given information is likely to be redundant or predictable from context. It remains to be investigated, however, to what extent repetition reduction occurs in languages with fundamentally different prosody. Prosodic effects of word redundancy have been explained by the Smooth Signal Redundancy Hypothesis (SSRH, Aylett & Turk, 2004), which presents prosodic reduction as a means of safeguarding robust oral communication. To what extent the predictions of the SSRH (Aylett & Turk, 2004) hold cross-linguistically, however, remains to be investigated. A literature review presented in the current study shows that in most studies on repetition reduction, participants were speakers of English. Given the use of pitch accents in this language, the reduction effects have been partially attributed to typical intonation phenomena in Germanic languages (Bard et al., 2000; Lam & Watson, 2014). In addition, it is not clear which acoustic cues signal repetition reduction across languages. The literature finds consistent effects of repetition on duration. However, the role of other cues in repetition reduction, in particular the role of F0, has been investigated to a lesser extent and with inconclusive results, as further discussed in section 1.5.

To further investigate general claims on repetition reduction and to acquire possible new insights into the use of prosodic prominence, more work is needed on under-researched languages. In the current study, we focus on Papuan Malay, a variety of Eastern Indonesian Trade Malay, spoken in Papua, Indonesia (Paauw, 2008). The majority of recent investigations on the prosody of Papuan and Ambonese Malay, another closely related variety of Eastern Indonesian Trade Malay, suggest substantial differences compared to the prosody of Germanic languages (Maskikit & Gussenhoven, 2016; Riesberg, Kalbertodt, Baumann & Himmelmann, 2018). Therefore, it remains to be seen to what extent speakers of Papuan Malay reduce repeated words prosodically and, if so, which acoustic parameters are affected. In the current study we focus on lexical repetition effects only, as these have been studied extensively in recent decades. Moreover, no corpus data is currently available to study the lexical frequency or probability of Papuan Malay words.

The remainder of the introduction is organized as follows: section 1.1 introduces and section 1.2 reviews work on prosodic reduction of repeated words. Particular attention is given to the comparison between repetition reduction and accentuation (section 1.3). Subsequently, in section 1.4 an overview of the work on prosody in Trade Malay varieties is given, with particular focus on Papuan Malay. In section 1.5 the research questions and hypotheses are formulated.

1.1 Repetition reduction in prosody

Experimental research has consistently shown that word repetition leads to reduction in acoustic cues to prosody. Many studies report production data (i.e., acoustic measures) while a few have investigated the extent to which prosodic reduction is perceptually relevant. The remainder of this section provides a discussion of the experimental literature on repetition reduction. The current study clearly distinguishes repetition proper from notions such as givenness, which originates from the literature on focus marking (section 1.3). Therefore, the main focus of the review is on studies that report prosodic reduction effects due to repetition (i.e., studies where *repetition* is used to describe the effects and not *focus* or *givenness*). There are a considerable number of studies investigating the prosodic realization of focus cross linguistically, which also covers the prosody of given information and which might involve repeated words. However, these studies do not directly address repetition effects and commonly make use of question-answer sequences (i.e., manipulated discourse structures) to elicit different focus types (e.g., Burdin et al., 2015; Fiedler & Jannedy, 2013). Studies on repetition reduction, on the other hand, include either spontaneous speech from corpora or semi-spontaneous dialogues from experimental tasks in which referential structures are generally not manipulated. The current review does include studies on focus marking in as much as they explicitly disentangle these effects from those of repetition. Furthermore, the review is limited to reported effects of repetition on prosody, even when other aspects were covered in the same study. Because the studies diverge with respect to their theoretical backgrounds, interpretations of the repetition results reported therein are generally not included in the current review. Studies are compared on key aspects such as: main experimental variables of interest, measure of repetition, the type of data collected (i.e., word type), acoustic cues measured and language under investigation. In order to compare duration reduction across studies, ratios were computed by dividing the (normalized) duration value of the second mention by the (normalized) duration value of the first mention, in as much as these values were reported in the studies. The next section provides a written summary of the key aspects, whereas Table 1 and Appendix A in the Supplementary Material provide a schematic summary and a more detailed discussion of the studies, respectively.

Written summaries are provided in Appendix A and numbered accordingly.

1.2 Summary of the literature on repetition reduction

Taken together, the reviewed studies show that lexical repetition of a word can cause prosodic reduction, although word frequency and predictability do have separate effects too (Aylett & Turk, 2004; Lam, 2012; Wiener, Speer & Shank, 2012). Many studies have conducted experiments on repeated mentions whilst varying the discourse setting (monologue/dialogue; e.g., McAllister, Potts, Mason & Marchant, 1994), the accessibility of information for either speaker or listener (e.g., Bard et al., 2000) and the spontaneity of the produced speech (scripted naming tasks/spontaneous speech corpora; e.g., Baker & Bradlow, 2009; Fowler, 1988). Measures of repetition were generally acoustic, although some studies also provided word count data to study the interaction between repetition and frequency or predictability effects (e.g., Bell, Brenier, Gregory, Girand & Jurafsky, 2009). Acoustic measures mostly included duration (either raw or normalized) and to a lesser extent F0 and/or intensity (e.g., Lam & Watson, 2010; Klassen & Wagner, 2017). In the overall majority of cases, the language for which the repetition effects were studied was a variety of English. Exceptions were Dutch (Pluymaekers, Ernestus & Baayen, 2005), Thai (Vajrabhaya & Kapatsinski, 2011), Korean (Lam, 2012; Lam & Marian, 2015) and Mandarin (Wiener et al., 2012).

Although the reviewed studies differ with respect to their theoretical background, the SSRH (Aylett & Turk, 2004) in particular provides a testable framework that explains many of the repetition reduction effects found in the literature. The SSRH states that stable (i.e., smooth) language redundancy levels facilitate communication and that these can be achieved due to an inverse relationship between duration and redundancy. That is, low redundancy levels (e.g., first mentions) are expressed by long durations whereas high levels of redundancy (e.g., second mentions) are

Table 1. Chronological overview of studies reporting acoustic effects on prosody due to repetition (other reported effects are not listed).

No.	Study	Data	Main variable of interest	Word type	Acoustic measures	RED R	Language
A.1	Fowler & Housum (1987)	RTV monologue corpus	Context/isolation	N/V	DUR*, F0, INT	0.89	~US E.
A.2	Fowler (1988)	Read/spontaneous speech	List/context	N/V	DUR*	0.94	US E.
A.3	Bard et al. (1989)	Corpus of dictated speech	Fluent/disfluent speech	n/a	(perception only)	n/a	~UK E.
A.4	Shields & Balota (1991)	Sentence recall task	Identical/semantically related	N/ADJ	DUR*, INT*	0.94	US E.
A.5	McAllister et al. (1994)	Tangram task	Monologue/dialogue	N (idiosyncratic)	DUR*	0.97	NZ E.
A.6	Fowler et al. (1997)	Spontaneous narrations	(dis)continuity markers	N (character names)	DUR*	0.91	US E.
A.7	Bard et al. (2000)	HCRC Map Task Corpus	Audiovisual accessibility	N (landmarks)	N-DUR*	0.79	UK E.
A.8	Anderson & Howarth (2002)	HCRC Map Task Corpus	Same/different speaker	N (landmarks)	DUR*	0.91	UK E.
A.9	Aylett & Turk (2004)	HCRC Map Task Corpus	Redundancy	N (landmarks)	N-DUR*	n/a	UK E.
A.10	Pluymaekers et al. (2005)	Spontaneous speech corpus	Repetition/predictability	Suffix –*lijk*	DUR*	n/a	Dutch
A.11	Trón (2008)	HCRC Map Task Corpus	Repetition/recency/speaker effects	Content/function	DUR*	n/a	UK E.
A.12	Baker & Bradlow (2009)	Reading task	Normal/clear speech style	N/V/ADJ/PN/DET/PP/CJ	DUR*	0.94	US E.
A.13	Bell et al. (2009)	Switchboard Corpus	Repetition/frequency/predictability	N/V/ADJ/ADV	N-DUR*	n/a	US E.
A.14	Lam & Watson (2010)	Picture naming task	Repetition/predictability	N	DUR*, F0, INT	0.95	US E.
A.15	Vajrabhaya & Kapatsinski (2011)	Picture naming task	Speaker/listener effects	N (vowel duration)	N-DUR*	n/a	Thai
A.16	Lam (2012)	Picture naming task	Repetition/predictability	N	DUR*, F0*, INT* DUR*, F0*	0.95 0.93	US E. Korean
A.17	Wiener et al. (2012)	Sentence reading task	Repetition/frequency/phrase position	N	*DUR	0.98	Mandarin
A.18	Lam & Watson (2014)	Event description task	Lexical/referential repetition	N	DUR*, INT*	0.94	US E.
A.19	Jacobs et al. (2015)	Event description task	Auditory memory	N	DUR*, F0*	0.92	~US E.
A.20	Kahn & Arnold (2015)	Picture naming task	Auditory priming speaker/listener	N	DUR*	0.89	~US E.
A.21	Lam & Marian (2015)	Event description task	Repetition/bilingualism	N	DUR*, INT*	0.98	US E.+Kor.
A.22	Klassen & Wagner (2017)	PC-mediated dialogue	Focus structures	N	N-DUR, F0, INT*	n/a	US E.

*significant effect.
N: normalized duration measures; RED R: reduction ratio, expressed as mean (normalized) duration of repeated mentions relative to first (non-repeated) mention when reported in the study (otherwise n/a); ~: languages that were not explicitly reported in the study and therefore inferred from the authors' affiliations/laboratories (E.: English; Kor.: Korean).
N: noun,; V; verb; ADJ: adjective; ADV: adverb; PN: pronoun; DET: determiner; PP: preposition; CJ: conjunction.

expressed by short durations. While smoothing signal redundancy is claimed to be a universal principle, languages may differ by the means they use to achieve the smoothing. Before discussing the studies on prosodic reduction of repeated mentions it is therefore crucial to note that non-prosodic means (i.e., word order shifts) to obtain a smooth signal could be used as well. Furthermore, it should be noted that the SSRH is based on data which was coded for prosodic structure following a "culminative prominence hierarchy" (Aylett & Turk, 2004, p.40). In such a hierarchy, only full vowels bear word stress and only stressed syllables bear phrase accents. This hierarchy applies to the prosody of English. However, evidence from other languages indicates that phrase accents can occur irrespective of whether the language has word stress (e.g., Gordon, 2014 for a typological overview). Recent studies on Papuan Malay suggest that naïve native listeners do not agree on phrasal prominence judgments (Riesberg, Kalbertodt, Baumann & Himmelmann, 2018), while there is acoustic evidence for consistent word stress patterns (Kaland, 2018). It remains to be seen, therefore, to what extent the underlying hierarchy used to analyze English is equally useful for the analysis of other languages, in particular those in Indonesia (Himmelmann, 2018; Kaufman & Himmelmann, accepted). As suggested by the SSRH (Aylett & Turk, 2004), the effects of redundancy on prosody are expected to vary across languages, depending on the specific use of prosodic prominence in these languages. In the following, several further, more specific observations are derived from the literature on repetition reduction, which will be scrutinized in the current investigation.

First, the reviewed studies mostly investigated the production of repeated mentions, although three (also) focused on perception: Fowler & Housum (1987), Bard, Lowe & Altmann (1989) and Klassen & Wagner (2017). Perception experiments are particularly useful to test the extent to which observed acoustic effects are relevant for listeners. Such investigations shed light on the communicative role of repetition reduction and could further refine hypotheses about which acoustic cues are actually used by the listener. The three studies just mentioned indicate that repeated mentions presented in isolation are less intelligible than first mentions, in line with the predictions for speech production in the SSRH (Aylett & Turk, 2004). However, more perception research on repeated mentions is needed in order to substantiate these findings. For this reason, the current study also includes a perception experiment.

Second, the reviewed studies mainly investigated repetition reduction for content words. Function words are often not investigated. Following the hypothesis that content words generally have low redundancy levels compared to functions words, the repetition effects are predicted to differ accordingly. Work that compared function words with content words indeed found less reduction for the former (Bell et al., 2009; Trón, 2008). To substantiate the potential universality of this difference, more work needs to be done that takes both word types into account.

Third, concerning acoustics, it appears that duration is the most consistent acoustic cue to repetition reduction. At least, this is the acoustic parameter most frequently investigated in this context. Other prosodic measures such as F0 or intensity either showed inconsistent effects or were not investigated. The reported ratios of duration reduction varied between 0.79 (Bard et al., 2000) and 0.98 (Lam & Marian, 2015; Wiener et al., 2012), with an average of 0.93 among the studies for which a reduction ratio could be computed.

Fourth, while it is clear that a number of factors influence the occurrence and the extent of repetition reduction, it is still a matter of debate as to which cognitive mechanisms underlie it. The core issues are outlined in the following.

To begin with, repetition reduction is influenced by whether the two mentions of a given word occur in a coherent stretch of discourse or in a list of words, where they both refer to the same concept (Fowler & Housum, 1987; Shields & Balota, 1991). More specifically, repetition reduction occurs mainly within and not across clearly delimited discourse contexts such as episode boundaries (Fowler, Levy & Brown, 1997) and story (re)tellings (Vajrabhaya & Kapatsinski, 2011). Other pragmatic factors that are claimed to influence repetition reduction include who uttered the first mention (Anderson & Howarth, 2002; Kahn & Arnold, 2015; Trón, 2008), speaking style (Baker & Bradlow, 2009; Bard et al., 1989) and discourse setting (monologue/dialogue; McAllister et al., 1994). Apart from the reduction mechanisms that occur when two mentions have a meaningful relationship in the referential discourse (structure), repetition reduction also occurs with homophonous words that do not share referential similarity. Although both types of repetition often co-occur, studies have shown the importance of distinguishing discourse factors such as predictability from word factors such as lexical similarity (Lam, 2012; Lam & Marian, 2015; Lam & Watson, 2014; Wiener et al., 2012). As for the latter, this distinction reveals the influence of the speaker's auditory memory on the degree of repetition reduction, as argued in a number of recent studies (Kahn & Arnold, 2015, Jacobs, Yiu, Watson & Dell, 2015). Note, however, that this finding can equally well be explained by motoric processes. Research has shown that upon rapidly repeating specific motoric movements, the movements themselves become more accurate and take less time to produce (e.g., Elliot, Hansen, Mendoza & Tremblay, 2004; Khan, Franks & Goodman, 1998). Similar observations have been made for the motoric processes that underlie speech (e.g., Schulz, Stein & Micallef, 2001). Thus, repetition reduction between lexically similar (homophonous) mentions seems to originate from auditory and/or motoric routines that are activated due to the mere phonetic similarity of the two mentions.

In sum, we can distinguish two types of factors that drive repetition reduction. On the one hand, referential similarity between first (new) and second (given) mentions within one meaningful and coherent discourse is a major factor. On the other hand, phonetic similarity causes reduction, regardless of whether first and second mentions are semantically related. A conceptually similar distinction between concept-level and word-level repetition has been made in Lam and Marian (2015).

Finally, we return to the observation that the speech data used in most studies concerned a variety of English. While other languages could provide challenging test cases for the predictions of the SSRH (Aylett & Turk, 2004), the English bias in repetition reduction studies relates to a more fundamental shortcoming in the behavioral sciences. It has been shown that a variety of cognitive processes have been claimed to be universal, despite the behavioral data used to support these claims being almost entirely collected from participants belonging to Western Educated Industrialized Rich and Democratic (WEIRD) societies (Henrich, Heine & Norenzayan, 2010). The argument goes further in claiming that WEIRD societies in particular provide atypical data given how humans have lived over the course of history (but see reactions in Henrich et al., 2010). Most of the repetition reduction studies discussed above have discussed "universal phenomena" on the basis of mainly one "WEIRD" language. In the literature reviewed, repetitions produced by English-native speakers have been held as representative of cognitive processes underlying information processing (e.g., Kahn & Arnold, 2015; Shields & Balota, 1991), speaker–listener interactions (e.g., Bard et al., 2000; Fowler & Housum, 1987; McAllister et al., 1994; Trón, 2008), the production of referring expressions (Lam, 2012; Lam & Watson, 2014) and speech production (e.g., Aylett & Turk, 2004, Jacobs et al., 2015). It remains to be seen to what extent these processes work similarly across other languages of the world. The bias towards English is particularly problematic for studying the prosody of repetition reduction, because semantically-related repetitions coincide with accentuation strategies in this language. From the acoustic measures in the literature it was not always possible to conclude which of these factors caused the prosodic reduction. This issue will be further discussed in the next section in order to highlight the importance of disentangling the different factors underlying repetition reduction in prosody.

1.3 Accentuation and repetition reduction

As shown in several studies reviewed above, repetition reduction and prosodic marking of information status by means of accentuation are two closely related, yet separate phenomena. The acoustic cues that underlie prosodic prominence are F0, duration and intensity (Streefkerk, 2002; but see Kochanski, Grabe, Coleman & Rosner, 2005). These acoustic cues are involved in both accentuation and repetition reduction, although their primary correlates differ in that F0 is taken as the main correlate for phrase accentuation (e.g., Pierrehumbert & Hirschberg, 1990) and duration is widely considered to be the main correlate for repetition reduction (Table 1). Therefore, it has not always been clear in previous research to what extent F0 and duration reduction were the result of repetition and/or accentuation effects (Bard et al., 2000). Furthermore, both phenomena correlate with the discourse status of words. Typically, new information in discourse is produced with prosodic prominence, which is realized by means of pitch accents in various Germanic (and other) languages, including English (Ladd, 2008). Given information is typically deaccented in these languages and is therefore acoustically less prominent. There is overlap in that first mentions tend to be discourse-new and repeated mentions tend to be discourse-given.

Thus, repetition reduction often goes hand in hand with deaccentuation in Germanic languages, raising the question whether one phenomenon is actually the epiphenomenon of the other. The available studies on English that carefully controlled for accentuation, however, did find effects of repetition proper (Baker & Bradlow, 2009; Bard et al., 1989; Klassen & Wagner, 2017). In addition, studies have shown that phonetic similarity between two mentions causes reduction, regardless of their information status in the discourse (see section 1.2). These outcomes seem to indicate that repetition reduction can occur irrespective of language-specific intonation phenomena.

It is known that intonation differs widely among the languages of the world (Ladd, 2008), whereas prosodic reduction of repeated mentions can be explained by universal mechanisms related to auditory memory and speech motor processes. For example, Jacobs et al. (2015) found reduction for repeated words that were homophonous to the first mention, which was interpreted as an effect of auditory recency rather than an effect of a change in information status. It remains to be seen therefore, whether there is robust crosslinguistic evidence for the prosodic reduction of repeated mentions. In the current study we investigate to what extent repetition reduction occurs in Papuan Malay, a language in which the intonation differs in important regards from English and other Germanic languages, as discussed in the following section.

1.4 Prosody in Trade Malay varieties

Papuan Malay is a contact variety of Malay spoken in the Indonesian provinces Papua and West-Papua. It belongs to the Eastern Indonesian Trade Malay varieties, together with Ambonese, Banda, Kupang, Larantuka, Manado and North Moluccan Malay (Hammarström, Forkel & Haspelmath, 2017). These varieties show similarities in their phonology, morphology and syntax (Paauw, 2008). At the same time, the different Trade Malay varieties have undergone independent developments, as they are spoken on different islands of the vast Indonesian archipelago. A limited number of studies discussed below have investigated prosodic aspects of Trade Malay varieties and the extent to which these aspects relate to word stress and/or phrase accents (Himmelmann, 2018; Van Zanten, Stoel & Remijsen, 2010).

The existence of lexical stress has been claimed for all Trade Malay varieties; Kupang Malay (Steinhauer, 1983), Ambonese Malay (Van Minde, 1997), Tidore (North Moluccan Malay; Van Staden, 2000), Manado Malay (Stoel, 2007), Larantuka Malay (Paauw, 2008), Ternate (North Moluccan Malay; Litamahuputty, 2012) and Papuan Malay (Kluge, 2017). Similarly, for Indonesian, word stress has been assumed to exist (Laksman 1994; Odé 1994; see Van Heuven & Van Zanten, 2007, for a discussion). In all these studies, stress is assumed to be regularly located on the penultimate syllable and to move to the ultimate syllable in specific conditions (e.g., when the penultimate syllable contains schwa). Crucially, however, most of the stress claims are based on the auditory impressions of the predominantly Western authors. Empirical work on perception has shown that Indonesian listeners have no preference for the location of stress (Goedemans & Van Zanten, 2007) and stress might therefore not exist (Van Heuven & Van Zanten, 2007). With respect to Trade Malay varieties, Ambonese has been analyzed as a language without stress (Maskikit-Essed & Gussenhoven, 2016), whereas for Papuan Malay consistent acoustic evidence for word stress has been found (Kaland, 2018).

As for post-lexical prosody, a small number of studies investigated the prosodic marking of information structure and the use of pitch accents and prominences. Several of these studies did not carry out in-depth acoustic analyses or are limited to a few acoustic cues. Major rise-fall F0 excursions are typically found on the last two syllables of a phrase across Trade Malay varieties (Himmelmann, 2018). In Manado Malay, there is evidence from F0 contours for the prosodic marking of focus on the subject, object, verb or predicate (Stoel, 2007). The element in focus is generally produced with a larger F0 excursion compared to the element out of focus. The prosodic differences in these focus realizations, however, are only found at the right edge of the phrase. Crucially, there is no acoustic evidence for narrow focus marking in Manado Malay prosody. Similarly, identical F0 contours in corrective focus and post-focus conditions are found in Ambonese Malay (Maskikit-Essed & Gussenhoven, 2016). The regular F0 movements at the end of Ambonese phrases are analyzed as floating boundary tones, because of their weak temporal integration.

Further work that suggests the absence of pitch accents is provided by a perception study (Riesberg et al., 2018), in which agreement between native ratings of prosodic prominences and boundaries was investigated. Results showed considerably more agreement for boundaries compared to prominences. An analysis of which prosodic cues contributed to the agreement showed the strongest effects for duration and no effects for F0. It was concluded that the prosody of Papuan Malay has a demarcative function rather than a prominence-lending function, and is therefore not likely to have pitch accents. Although these initial findings need further investigation to complete the picture on focus marking in Papuan Malay, they suggest a minor role for F0 in phrase level prosody.

To conclude, Papuan Malay and Germanic prosody differ in important regards. However, the latter alone has guided much of the experimental work and influenced most of the theoretical modelling. Most importantly in the current context, there is no conclusive evidence for the use of F0 to mark information structure in Papuan Malay. The little research available suggests that Papuan Malay prosody does not mark information structure. This provides the opportunity to investigate repetition reduction without the possible confounding effect of information structure on prosody.

1.5 Research questions

The studies discussed in the introduction show that there is a robust effect of prosodic reduction due to repetition, which could be explained by language universal principles such as signal redundancy smoothing (SSRH; Aylett & Turk, 2004). However, the evidence for repetition reduction is largely based on varieties of English, which is not representative of the world's languages. More specifically, it is known that Germanic languages make specific uses of prosodic marking such as accenting new information and deaccenting given information. Except for evidence from Korean (Lam, 2012), it is not clear whether prosodic reduction due to repetition also occurs in languages that do not have these accentuation strategies. The current study investigates such a language, Papuan Malay, where prosody is assumed to not mark information status. Furthermore, the current study investigates both the production and perception of repeated mentions. The latter aspect has been investigated in a limited number of studies and never for other languages than English.

We hypothesize that speakers of Papuan Malay reduce repeated words prosodically. This prediction follows from the literature in three ways. First, durational shortening is the crucial acoustic correlate involved in presumed crosslinguistic processes related to redundancy (Aylett & Turk, 2004). Second, a limited number of studies reported repetition reduction in duration for languages other than English (i.e., Thai: Vajrabhaya & Kapatsinski, 2011; Korean: Lam, 2012; and Mandarin: Wiener et al., 2012). Third, repeated mentions in Papuan Malay are also expected to have reduced intelligibility on the basis of earlier perception studies (Bard et al., 1989; Fowler & Housum, 1987). In other words, the cognitive mechanism that smoothens the redundancy of the speech signal in order to maintain robust communication is assumed to be equally important for speakers *and* listeners in any spoken language.

Alternatively, it could be the case that speakers of Papuan Malay do not prosodically reduce repeated mentions. Previous work suggested that the main function of Trade Malay prosody is to mark boundaries rather than to mark prominences (Maskikit-Essed & Gussenhoven, 2016; Riesberg et al., 2018). Following these conclusions, it is plausible that the redundancy of repeated mentions is signaled by means of different prosodic cues, or is not signaled by prosodic prominence at all. In the case that prosodic reduction does not occur in Papuan Malay, this language may have non-prosodic means to smoothen signal redundancy, a possibility suggested in Turk (2010). In the current study, this could mean that repeated mentions in Papuan Malay hold particular phrase positions, for example. This possibility is briefly discussed in section 2.6.

Apart from this basic issue, the preceding literature review has revealed further unresolved issues regarding prosodic repetition reduction. One issue pertains to the question of which prosodic parameters are affected by the reduction. All studies have found duration to be affected, and hence we also expect duration to provide the primary evidence for prosodic repetition reduction in the current study. As for F0, it is harder to make clear hypotheses, given the inconsistent results on F0 in the literature on repetition reduction (Table 1). The repetition reduction studies that considered F0, generally predicted that higher F0 is associated with higher degrees of prominences, which are often used to mark new information (low redundancy). On the basis of intonation models (e.g., Ladd, 2008, Pierrehumbert & Hirschberg, 1990) prominence levels depend on the type of pitch accent, with rising pitch accents perceived as more prominent compared to falling pitch accents (Baumann & Röhr, 2015). It is however unclear to what extent studies on mainly Germanic languages provide valid predictions for Papuan Malay. In particular, when it comes to smoothing redundancy, the SSRH (Aylett & Turk, 2004) predicts that much depends on the language-specific use of acoustic parameters such as F0. On the basis of the limited research on Papuan Malay and Trade Malay varieties, (F0-driven) prominences can be predicted to be irrelevant, with the potential exception of the ones in phrase-final position, because major changes in F0 appear to occur primarily in a two-syllable window at the end of the phrase. The inclusion of F0 in the current investigation is motivated not only by the fact that it has been suggested as a possible correlate of repetition reduction (Fowler & Housum, 1987; Jacobs et al., 2015; Klassen & Wagner, 2017; Lam, 2012; Lam & Watson, 2010), but also because it may provide an insight into the use of F0 in Papuan Malay, which is currently not well understood. Intensity was not taken into account in the current study due to the uncontrolled distance between speaker and microphone in the recording (see section 2.1).

Another issue that remains to be clarified is the question whether repetition reduction affects all word types in the same way or whether content words differ from function words in this regard.

Based on previous research (Bell et al., 2009, Trón, 2008), we furthermore predict that repeated content words are reduced more than repeated function words.

In order to test the hypotheses, two experiments were carried out. In a production experiment speakers of Papuan Malay retold a short story. Repeated mentions in the story were then analyzed acoustically to investigate any effects of prosodic reduction (section 2). In particular, the repetition effects on duration and F0 were investigated for both content and function words. Subsequently, a perception test was carried out to investigate the extent to which the intelligibility of the repeated mentions was affected (section 3). A general conclusion and discussion is given in section 4.

2 Production analysis

To investigate the extent to which speakers of Papuan Malay prosodically reduce repeated mentions in discourse, a story retelling task was carried out. In this task, speakers were instructed to watch a short video clip and retell what they had seen to an interlocutor who had not been shown the video. The video clip showed a short story about a man picking pears. The actors in the video clip did not use any speech. The video clip has been used previously in cross-linguistic studies on narrative production (Pear Film; Chafe, 1980).

2.1 Design and procedure

Recordings were made at the Center for Endangered Languages Documentation (CELD) in Manokwari, West Papua (Riesberg & Himmelmann, 2012–2014). Participants received instructions about the experimental procedure before the start of the task. They were verbally instructed to watch the video clip in order to retell the story to an interlocutor who had not seen it. The video clip was shown to the participants on a laptop computer and lasted six minutes. Thereafter, participants were introduced to their interlocutor and were instructed to retell the story from the video clip. The participants and interlocutor were seated next to each other during the retelling. The interlocutor was allowed to ask clarification questions during the participant's retelling. This happened up to three times per participant. Participants were instructed to speak in Papuan Malay, their native language.

No soundproof or silent rooms were available at the recording location. Therefore, recordings were made outside, behind a building where background noise was as minimal as possible. The recordings were made using a Sony ECM-MS957 microphone connected to a Sony HDR-SR11 portable video camera. The microphone was placed in front of the participant and interlocutor and recorded the speech of both. The experimenter supervised the entire recording procedure. The duration of the collected recordings ranged between two and five minutes.

2.2 Participants

All participants were students at the University of Papua. There were 10 male and nine female participants (M_{age} = 22, age range 20–28). All were native speakers of Papuan Malay without speech problems. All participants were also speakers of Indonesian, the country's standard language. Seven participants had basic knowledge of another language (two Javanese, two Biak, one Mpur, one Abun and one English).

2.3 Data selection and acoustic analysis

Audio tracks were extracted from the recordings using the portable video camera and converted to 44.1 kHz, 16 bit, mono wave-files. Native speakers of Papuan Malay transcribed the participant's

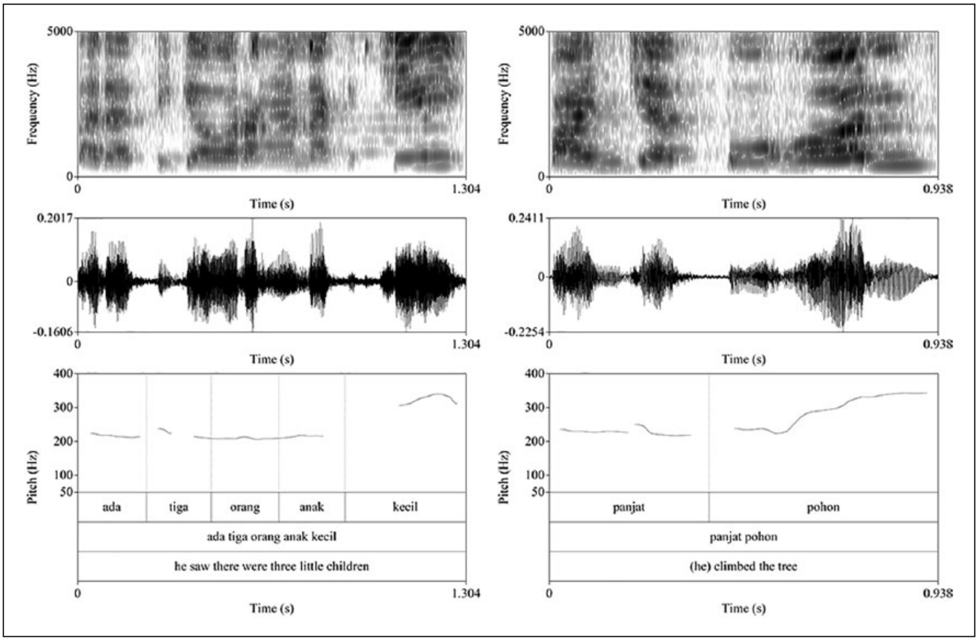

Figure 1. Two example spectrograms, waveforms and F0 contours (top to bottom panels) extracted from the collected Papuan Malay data with phrase final F0 excursions. Annotation layers from top to bottom: word (separated by vertical lines), phrase, English gloss.

speech and segmented it into intonation units (Chafe, 1994). The intonation units were defined on the basis of auditory boundary cues such as boundary tones and pauses. In a previous cross-linguistic comparative study, these boundaries were found to be perceived in highly similar ways for native and non-native speakers (see Himmelmann, Sandler, Strunk & Unterladstetter, 2018, for a detailed description of the boundary cues). Thereafter, a group of six labelers annotated all words produced by the participants for each wave file using Praat textgrids (Boersma & Weenink, 2017). All labelers received general training in a phonetics course to set label boundaries by auditory and visual inspection of the wave-form. Prior to their task, the labelers received specific instructions and completed an example taken from the collected data as a means of training. Labelers made use of both auditory and visual (spectral) information provided in Praat (Boersma & Weenink, 2017). As for the auditory information, labelers were instructed to set the word boundaries in such a way that the word could not be identified as any other word than the one at hand; that is, neither containing sounds from neighboring words nor excluding segments that belonged to the word. As for visual information, labelers were instructed to use the spectrogram and, if necessary, formant drawings to decide on the location of the boundaries. In particular, vowel transitions could be more accurately segmented with the use of formant information (see Figure 1; between *tiga* and *orang*). Specific instructions were given for cases in which the transition between two neighboring speech sounds made it impossible to single out either sound without co-articulatory information from its neighbor. In these cases, labelers were instructed to identify the entire interval for which they heard cues for both neighboring sounds and take the midpoint of that interval as the boundary. In this way, each of the neighboring speech sounds consisted of an equal amount of co-articulatory information. The words that needed to be identified were known to the labelers thanks to the transcribed intonation units, which were kept as a reference when setting the boundaries. The boundaries set by the labelers were then checked and, where necessary, corrected by a trained phonetician. Figure 1 provides two examples of annotated speech samples.

A subset of the labelled words was selected on the basis of the following criteria. Words that were part of an utterance that was interrupted by an external source or cut off by the speaker were omitted. Reduplicated words (e.g., *tiba-tiba*) were omitted, whereas single occurrences (e.g., *tiba*) were taken into account. This was done because the reduplicated word has a fundamentally different temporal structure compared to the single occurrence, that is *tiba* in *tiba-tiba* is shorter compared to *tiba* as single occurrence. The occurrence of a reduplication could have affected later single occurrences of the same word. However, reduplications preceded second single mentions three times in the entire corpus and were therefore unlikely to affect the repetitions. To avoid prosodic effects related to phrase prosody in Papuan Malay, words that occurred in the final position of the intonation unit were omitted. As observed for other Trade Malay varieties (section 1.4), phrase-final words tend to exhibit rise-fall F0 movements, which could be prominence-lending (e.g., in order to mark boundaries). These movements were also present in the collected data (see Figure 1). Given the possibility that the last two syllables in the phrase were affected by this prominence pattern (cf. Ambonese Malay; Maskikit-Essed & Gussenhoven, 2016), words with any syllables in these positions were excluded. Furthermore, omitting phrase-final words also avoids interference between potential effects of repetition and those of phrase-final lengthening. Words that were lengthened due to hesitation were also omitted. Words with loud background noise (e.g., motorcycle, bird or clicks) were omitted as well. From the selected words one half consisted of first mentions and the other half consisted of second mentions. Some words had third, fourth or later occurrences. However, these were not taken into account as they occurred at an increased distance from the first mention, which could be confounded with topic or referential shifts. Furthermore, the subset was divided into content words (nouns, verbs, adverbs) and function words (demonstratives, conjunctions, question words, prepositions, negations, pronouns) based on word lists from Kluge (2017). Note that words that translate to adjectives in English are generally expressed by stative verbs in Papuan Malay (Kluge, 2017). The selected subset including both first and second mentions contained 856 content words and 436 function words. The number of words for which at least one repetition could be found ranged from 31 to 86 per speaker.

Using a script, three acoustic measures were taken from the selected words in Praat (Boersma & Weenink, 2017). First, raw word duration was measured, as this appeared the most reliable cue to repetition reduction (Table 1). The raw duration measures were not log-transformed, as the data did not need to be normally distributed to perform the statistical analyses (section 2.4), similar to the duration analysis in Lam and Watson (2014). Second, F0 range was measured by subtracting the minimum F0 of the word from the maximum F0 of the word. F0 range was chosen as many of the world's languages show a compressed F0 range in post-focal positions (Xu, 2011), which could apply to second mentions in the current study. Although it can be predicted that Papuan Malay does not mark focus prosodically, there is only indirect evidence to support this prediction (Riesberg et al., 2018). Taking into account F0 range, therefore, could provide additional insight into the use of F0 range in Papuan Malay. Third, F0 mean of the word was measured, as this measure is generally assumed to correlate positively with prosodic prominence, and has been used for this reason in repetition reduction studies (Fowler & Housum, 1987; Jacobs et al., 2015; Klassen & Wagner, 2017; Lam, 2012; Lam & Watson, 2010). F0 measures were checked for F0 tracking errors and were not taken into account for analysis if these errors had occurred.

Furthermore, it is known that micro-prosodic effects can interfere with F0 measures. Voiceless stops in particular disrupt F0 contours and are therefore often controlled for in research on (macro-)prosody (e.g., Hanson, 2009; Iivonen, Seppänen, Noponen, & Toivanen, 2009). In the

Table 2a. Mean duration (ms), F0 range (Hz) and F0 mean (Hz) and standard deviations of repeated content and function words.

Acoustic measure	Word type	First mention	Second mention
Duration	Content	273.63 (*112.97*)	259.81 (*102.37*)
	Function	218.54 (*125.77*)	199.49 (*94.40*)
F0 range	Content	32.72 (*25.40*)	33.60 (*24.24*)
	Function	29.42 (*23.60*)	30.99 (*22.54*)
F0 mean	Content	195.82 (*58.31*)	203.64 (*64.94*)
	Function	194.39 (*60.68*)	205.23 (*63.82*)

current study, such effects could not be entirely avoided given the spontaneous character of the speech data. That is, the choice of words was entirely free and unscripted. In particular, a final voiceless stop in the preceding word could have caused a significantly higher F0 in the initial vowel of the (first or second) mention. Manual inspection of the data confirmed this effect, as shown by octave-jumps. For this reason, the pitch setting in Praat (Boersma & Weenink, 2017) was adjusted such that the cost to analyze an F0 track with octave-jumps was higher (0.55 instead of the standard 0.45). Manual re-inspection was done to confirm that fewer octave-jumps occurred and that the tracked F0 level was the natural one and not the "jumped" one. To check for remaining effects of stops in the octave-jump-corrected material, a pre-analysis was carried out. This was done for all first and second mentions with initial vowels that immediately followed a final voiceless stop (/p/, /t/ or /k/ in the Papuan Malay data) in the preceding word. The mean F0 and F0 range of the words that did have a preceding voiceless stop ($N = 222$) were compared to the words that did not have these neighboring sounds ($N = 1070$). Linear mixed model (LMM) analyses (see section 2.4 for further details) fit by maximum likelihood (using Satterthwaite approximations to degrees of freedom to calculate *p*-values) were carried out on the F0 measures (mean and range in Hz) as dependent variable, with neighboring stop (2 levels: present, absent) as fixed deviation-coded (-0.5, 0.5) factor, and with participants (speakers) and items (words) as random intercepts, and with by-speaker random slopes for neighboring stops (i.e., the maximal converging model). The analyses revealed no significant effects of neighboring voiceless stops on F0 mean ($\beta = 0.35$, $SE = 0\ 4.13$, $t = -0.09$, n.s.) or on F0 range ($\beta = .15$, $SE = 1.97$, $t = .08$, n.s.). Furthermore, the frequency of occurrence of neighboring voiceless stops was similar for first ($N = 107$) and second ($N = 115$) mentions. These results were taken as an indication that the micro-prosodic influence on the F0 measures was minimal and was unlikely to interfere with the possible acoustic effects of repetition.

2.4 Statistical analysis

Statistical analyses were carried out using R (R Core Team, 2017) and the lme4 package (Bates, Maechler, Bolker & Walker, 2015). LMM analyses fit by maximum likelihood (using Satterthwaite approximations to degrees of freedom to calculate *p*-values) were carried out on the acoustic measures (duration in ms, F0 range and mean in Hz) as dependent variable, with (the interaction of) mention (2 levels: first, second) and word type (2 levels: content, function) as fixed deviation-coded (-0.5, 0.5) factors, and with participants (speakers) and items (words) as random intercepts, and with by-speaker random slopes for word type and by-word random slopes for mention (i.e., the maximal converging model structure). Mean values and standard deviations are given in Table 2a and the outcomes of the statistical tests are given in Table 2b.

Table 2b. Results of the linear mixed effect model analysis on acoustic measures of duration, F0 range and F0 mean.

Acoustic measure	Fixed effect	Estimate	*SE*	*t*	*p*
Duration	(Intercept)	259.84	9.71	6.56	< 0.001
	Mention	−20.30	5.01	−4.05	< 0.001
	Word type	57.42	14.83	141.30	< 0.001
	Mention*W.type	4.77	10.01	0.48	n.s.
F0 range	(Intercept)	32.50	2.09	15.55	< 0.001
	Mention	0.82	1.52	0.54	n.s.
	Word type	2.40	2.51	52.31	n.s.
	Mention*W.type	0.83	2.99	0.28	n.s.
F0 mean	(Intercept)	192.71	8.63	22.33	< 0.001
	Mention	8.80	3.05	2.89	< 0.01
	Word type	−2.65	5.01	−0.53	n.s.
	Mention*W.type	−4.29	6.02	−0.71	n.s.

*significant effect; n.s.: not significant.

2.5 Results

2.5.1 Duration. Results show a significant effect of mention (β = -20.30, SE = 5.01, t = -4.05, $p < 0.001$) in that second mentions (M = 239.45) were overall significantly shorter compared to first mentions (M = 255.04). The effect of word type (β = 57.42, SE = 14.83, t = 141.30, $p <$ 0.001) indicates that content words (M = 266.72) are significantly longer compared to function words (M = 209.02). The lack of an interaction effect between mention and word type indicates that there is no significant difference in repetition shortening between content words and function words.

2.5.2 F0 range. F0 range shows higher values for second mentions, for both content and function words (Table 2a). However, the (interaction between the) factors mention and word type are not significant.

2.5.3 F0 mean. Second mentions show significantly higher F0 values compared to first mentions (β = 8.80, SE = 3.05, t = 2.89, $p < 0.01$), both for content words (M_1 = 195.82, M_2 = 203.64) and for function words (M_1 = 194.39, M_2 = 205.23). The factor word type did not show any significant (interaction) effects.

2.6 Discussion

The result of the acoustic analysis showed that second mentions are shortened and at the same time have higher mean F0 values. Furthermore, none of the acoustic measures showed interaction effects between mention and word type, indicating that the observed main effects are similar for content words and function words.

As for durational shortening, this result is in line with the expected reduction for repeated mentions, as shown in numerous previous studies. This becomes clear when comparing the reduction ratios of content words (0.95) and function words (0.91), which results in the same overall average (0.93) observed in 15 studies (Table 1). The results for duration confirm the hypothesis that speakers of Papuan Malay reduce repeated words.

With respect to the two F0 measures (mean and range), results are less straightforward. That is, mean F0 is significantly higher for second mentions, regardless of word type. This is possibly reflected in larger F0 ranges for second mentions, although no significant effect is found for this variable. The observed effect on mean F0 in particular leaves several explanations open. F0 has been taken as a correlate of repetition reduction where higher levels were expected to signal higher levels of prominence (e.g., Lam, 2012). While not all forms of reduction have equal effects on all acoustic correlates, opposite effects for F0 and duration preclude the conclusion that prosodic reduction occurs uniformly. It could therefore be the case that language-specific use of F0 affected the repeated mentions in ways that are not yet well understood and possibly specific to Papuan Malay or Trade Malay prosody. Although more research needs to be done on F0 in Trade Malay varieties to explain this finding, we provide two potential explanations in the following paragraphs.

One explanation for the opposing effects of duration and F0 in the current results could reside in the assumption that different acoustic correlates have different linguistic functions. Such an explanation would be in line with the Multiple Source view on prominence (Watson, 2010). Under this view, acoustic correlates of prominence are disentangled and attributed different functions. That is, duration is associated with production difficulty, whereas both pitch and intensity are associated with marking important information for the listener. This view finds support in the existing literature. Traditionally, duration has been the main correlate considered in studies on repetition reduction (Table 1), whereas F0 movements have been taken as the main indicators of pitch accents and intonation in general (i.e., Ladd, 2008). With regard to the current results, it is plausible that duration indeed showed effects of repetition reduction, whereas F0 could relate to phrase intonation phenomena. It is however unclear which phrase intonation phenomena in particular could have played a role, as this aspect of Papuan Malay prosody has not yet been investigated. Furthermore, it should be noted that an influence of Indonesian cannot be fully excluded in the current study. Although participants were instructed to speak Papuan Malay, they had knowledge of Indonesian as a standard language. This could have influenced their prosody to some extent. However, the available research on either language reports common phrase final pitch movements, which were therefore excluded in the current study, as discussed in section 2.3. Therefore, the influence of Papuan Malay or Indonesian phrase prosody on F0 are likely to be minimal.

Another hypothetical explanation for the diverging acoustic effects may be found in the narrative style of Papuan languages. That is, speakers tend to fully or partially repeat the last clause of the previous phrase in the next phrase, also called tail–head linkage (e.g., De Vries, 2005). Consider the following example from the Papua language Usan (De Vries, 2005, p. 374): "Having got (the firewood) we started a fire. After lighting the fire, we cut up the pig." Typically, the noun (clause) in the tail of one phrase is repeated in the head of the subsequent phrase. In the current data, it is plausible that first mentions generally occurred late in the phrase, whereas the second mention generally occurred early in the subsequent phrase. In addition, the F0 baseline generally declines over the course of a phrase (Breckenridge, 1977), such that second mentions could have had a higher mean F0 compared to first mentions. To explore this possibility, the narrative part of the phrase was labelled such that words occurring in the first half of the phrase were labelled "head." and words occurring in the second half of the phrase were labelled "tail." In addition, the linkage between the first and second mention was labelled as either "subsequent" when they occurred in two subsequent phrases or "other" when they occurred in the same phrase or more than one phrase away from each other. An LMM analysis was carried out on the mean F0 values with (the interaction between) mention (first, second), narrative part (head, tail) and linkage (subsequent, other) as fixed deviation-coded (-0.5,.5) factors and with participants (speakers) and items (words) as random intercepts, and with by-speaker and by-word random slopes for mention, narrative part and linkage (i.e., the maximal converging model structure). Results show a significant effect of mention ($\beta = 7.80$, $SE = 3.85$, $t = 2.02$, $p < 0.05$) confirming the main effect on F0 mean reported in section 2.5. No significant (interaction) effect involving any of the other fixed factors was found. Furthermore, the overall frequency of subsequent tail–head links in the data was assessed. This was done by counting instances in which second mentions occurred in the phrase directly following the phrase containing the first mention. This happened for 17.96 % of the words ($N = 232$, i.e., 166 repetition pairs). From this subset, another selection was made by taking only content words, as these are expected to occur more frequently in tail–head links than function words. A post-hoc chi-square test on the distribution of first and second mentions of content words in the head or tail was carried out to test whether content words indeed occurred mostly in the tail when mentioned for the first time and occurred mostly in the head when mentioned for the second time (i.e., the subsequent phrase in this data subset). Such an outcome would be expected if tail–head linkage is indeed part of the Papuan Malay narrative style. The test revealed significant differences: $\chi^2(1, N = 166) = 15.06$, $p < 0.001$), such that more first mentions were found in the tail ($N = 55$) compared to the head ($N = 28$) and more second mentions were found in the head ($N = 54$) compared to the tail ($N = 29$). In sum, these results indicate that tail–head linkage occurs in Papuan Malay spontaneous narratives. However, the occurrence of tail–head links does not seem to explain the repetition effect on the F0 mean.

In addition, Papuan Malay could make use of more fine-grained word position changes to smooth the signal redundancy in a phrase. This possibility is discussed in the SSRH (Aylett & Turk, 2004) as an alternative to prosodic means of smoothing (see also section 1.2). In order to evaluate whether phrase positions significantly differed between first and second mentions, and between content and function words, an additional LMM analysis was carried out on a relative measure of phrase position taken for all first and second mentions in the collected data. That is, relative phrase position of a word was computed by subtracting the total number of words in the phrase from the position of that word in the phrase. This was done to abstract over varying phrase lengths, such that a word occurring third in a phrase of five words, would get a relative phrase position of $3/5 = 0.6$. The same value would be assigned for the sixth word in a 10-word phrase, etc. The LMM analysis was carried out on the relative phrase position values as dependent variable, with (the interaction of) mention (two levels: first, second) and word type (two levels: content, function) as fixed deviation-coded (-0.5, 0.5) factors, and with participants (speakers) and items (words) as random intercepts, and with by-speaker random slopes for (the interaction of) mention and word type, and by-word random slopes for mention (i.e., the maximal converging model structure). Results showed that the relative position of first mentions ($M = 0.54$, $SD = 0.24$) and second mentions ($M = 0.52$, $SD = 0.23$) did not differ ($\beta = -0.02$, $SE = 0.02$, $t = -1.15$, n.s.). There was an effect of word type ($\beta = 0.05$, $SE = 0.02$, $t = 2.46$, $p < 0.05$) in that function words occurred earlier in the phrase ($M = 0.50$, $SD = 0.25$) than content words ($M = 0.55$, $SD = 0.23$). The interaction between mention and word type was not significant. Thus, this analysis indicates that second mentions in Papuan Malay do not hold a different phrase position compared to first mentions, which could have indicated structurally different ways of handling the redundancy of either mention. A fine-grained syntactic annotation would allow for a more detailed analysis of potential effects of phrase position. This is, however, beyond the scope of the current study.

In sum, the production data have shown effects that partially confirm and partially nuance current work on repetition reduction. It remains to be investigated to what extent listeners hear a difference between first and second mentions. Previous work found that shortened second mentions presented in isolation were harder to identify in a word recognition task (Bard et al., 1989; Fowler & Housum, 1987). It remains unclear from the current production data to what extent prosody is

Table 3. Example set of 8 Papuan Malay words taken from a random speaker to illustrate the design of the perception experiment. English translations are provided in the right-hand column.

	First mention	Second mention	English
Content words	*pace*	*pace*	man
	angkat	*angkat*	to lift
Function words	*dong*	*dong*	they
	dengan	*dengan*	with

uniformly reduced, and therefore to what extent the intelligibility of repeated mentions is affected. Therefore, a perception experiment was carried out to investigate possible recognition differences between first and second mentions. The next section reports this perception experiment.

3 Perception analysis

In order to investigate to what extent the intelligibility of repeated mentions was affected by the prosodic reduction found in section 2, a word recognition task was carried out.

3.1 Materials and design

The words presented in the task were a selected subset of the words analyzed in section 2. The selection was done in such a way as to obtain a counterbalanced design in which a bias for mention word type or speaker was avoided as much as possible. That is, 8 words were taken from each speaker who participated in the production task. These 8 words consisted of 4 first mentions (2 content words and 2 function words) and 4 second mentions (2 content words and 2 function words). Note that the second mentions were repetitions of the first mentions; i.e., concerning the same word as in the production data (Table 3). The resulting stimulus set thus consisted of 152 words (8 x 19). To reduce word learning effects, the number of uniquely occurring words in the selected stimuli was kept as high as possible. Based on this additional selection criterion, the maximum number of uniquely occurring words would have been 76, given that each word occurred in two mentions. However, the available words in the production data allowed only 69 uniquely occurring words. This was the case because seven words occurred more often (five words occurred twice, one word occurred three times).

Speech shaped noise was added to the stimulus words using Praat (Boersma & Weenink, 2017). This was done in order to prevent ceiling effects for the amount of correct word identifications. A signal-to-noise ratio of -3 dB was used to mix the word with the noise. This ratio has been shown to lower correctly identified words in isolation to approximately 50% (e.g., Miller, Heise & Lighten, 1951, p. 334). In this way, positive and negative deviations from 50% identification scores indicate ease and difficulty of recognition, respectively.

The word identification task presented all 152 stimulus words in a random order to each participant. The random order was different for each participant to counterbalance possible learning effects. For each stimulus word (target) participants were asked to identify the correct word by choosing among four options. The three incorrect words (distractors) were existing Papuan Malay words that matched the target for number of syllables and, as much as possible, for vowel quality. For example, when the target word was *jadi* typical distractors were *jatu, jalan* and *tadi*. The inclusion of distractors that were similar to the target was done to minimize the chance that the identification of one syllable would be sufficient to correctly identify the entire word. It is particularly

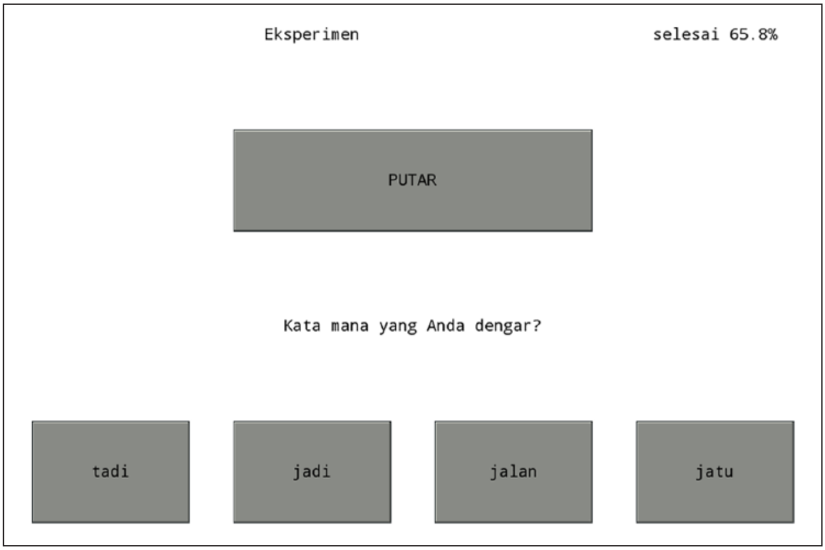

Figure 2. Screen capture with example stimulus in the perception experiment. Play button (*putar*) and the question "which word did you hear?" are provided in the center. The target word and three distractor words are displayed at the bottom. The top line shows the progress (*selesai*) in the experiment (*eksperimen*).

important to avoid such an effect in order to assess the potential perceptual effect of the acoustic differences due to repetition that concern the entire word (section 2).

3.2 Procedure

The word identification task was designed using OpenSesame (Mathôt, Schreij & Theeuwes, 2012). The experiment consisted of a script written in the programming language Python (Van Rossum & De Boer, 1991) and 152 wave files (target words). For each target word, the script generated a screen. The screen displayed a play button, four word buttons and a percentage counter (Figure 2). Clicking the play button would play the stimulus word, which could be played as often as needed. Each word button displayed a word on it such that one of them was the target word and three others were distractors. To choose one of the words, participants had to click on the word button on which the word of their choice was written. Only after the play button was clicked did the four word buttons appear at the bottom of the screen from left to right. This was done in order to make sure the participant had listened to the stimulus before making a choice. Thereafter, the next stimulus word would be presented. The order of the word buttons was shuffled such that words referring to distractors and targets appeared randomly in different positions.

Before the start of the experiment participants received verbal instructions about the course of the tasks. Then they took a seat behind a computer and completed three subsequent parts of the experiment. First, participants entered their personal data. Second, they received written instructions on the screen about their task. To familiarize themselves with the task, participants completed a practice round consisting of five words. At the end of the practice round participants were asked whether they felt they needed to practice more or whether they were ready to start the actual task. When more practice was needed, participants were presented with additional stimuli. After each additional practice stimulus, participants could end the practice round. Third, when participants

Table 4a. Mean correct identifications (standard deviations) of repeated content and function words.

Word type	First mention	Second mention
Content	0.62 (*0.49*)	0.66 (*0.48*)
Function	0.56 (*0.50*)	0.55 (*0.50*)

Table 4b. Results of the generalized linear mixed effect model analysis on the identification scores.

Fixed effect	Estimate	*SE*	*z*	*p*
(Intercept)	0.63	0.20	3.10	< 0.01
Mention	0.18	0.18	0.97	n.s.
Word type	0.41	0.32	1.31	n.s.
Mention * Word type	0.12	0.36	0.32	n.s.

*significant effect; n.s.: not significant

ended the practice session they were asked to start the actual identification task. Participants were instructed to switch off personal mobile devices and to use headphones during the entire experiment. After completing 50% of the actual identification task, participants were instructed to take a short break. The experiment lasted approximately 20 minutes. Identification scores were collected on the computer and stored as 1 or 0. That is, correct identifications were stored as 1, incorrect identifications were stored as 0.

3.3 Participants

In total 20 participants carried out the perception experiment. They were all students at the University of Papua; six male and 14 female participants ($M_{age} = 21.8$, age range 19–29). All were native speakers of Papuan Malay without hearing problems. They were given a small present for their participation.

3.4 Statistical analysis

Statistical analyses were carried out using R (R Core Team, 2017) and the lme4 package (Bates et al., 2015). Generalized LMM analysis fit by maximum likelihood (Laplace approximation) was carried out on the identification scores as dependent variable, with mention (two levels: first, second) and word type (two levels: content, function) as fixed deviation coded (-0.5, 0.5) factors, with participants and items (words) as random slopes, and with a by-participant random slope for word type and with a by-word random slope for mention (i.e., the maximal converging model). In addition, a one-sample Wilcoxon signed rank test was carried out to investigate whether identification choices were significantly different from chance level (0.25). Mean values and standard deviations are given in Table 4a and the outcomes of the statistical tests are given in Table 4b.

3.5 Results

The range of mean correct identifications (Table 4a) was similar to that found in previous studies in which noise was added to avoid ceiling effects (Miller et al., 1951). The results of the perception experiment show that, overall, participants' choices were different from chance level ($M = 0.60$, V

$= 3{,}875{,}100$, $p < 0.001$). Furthermore, the results showed no significant differences between the identification scores of first ($M = 0.59$) or second ($M = 0.60$) mentions (Table 4b). Although participants showed higher identification scores for content words ($M = 0.64$) than for function words ($M = 0.56$), the effect of word type was not significant. The interaction between mention and word type was not significant.

3.6 Discussion

Overall, it is likely that ceiling effects were successfully avoided by adding noise to the stimuli (section 3.1). However, it was not the case that identification was based on guesswork only. The identification scores were different from chance level, indicating that listeners relied on the speech signal to make their choices.

The perception experiment furthermore showed no evidence that listeners were better in identifying first mentions compared to identifying second mentions. This null result is counter to what might be expected on the basis of earlier studies (Bard et al., 1989; Fowler & Housum, 1987). These studies found that second mentions presented in isolation were harder to identify compared to first mentions. Identification scores in the current study show a small advantage for identifying content words compared to function words, which could be the result of the duration differences between the two word types. This explanation is, however, speculative, as no effects were found in the statistical analysis. How the results of the perception experiment relate to those of the production experiment is discussed in the next section.

4 General conclusion and discussion

This study has shown that repeated mentions in Papuan Malay are shortened, have a higher F0 and are equally recognizable compared to initial mentions. This outcome is partially compatible with current theories on repetition reduction. In particular, Papuan Malay repetition reduction does not imply reduced acoustic values for all prominence cues. Duration was reduced consistently between first and second mentions, supporting the literature on repetition reduction. In addition, the duration effects found in the current study are compatible with the way English has been shown to smooth signal redundancy (Aylett & Turk, 2004). This observation is not necessarily expected, given the prediction of the SSRH that redundancy levels are not dealt with in the same (prosodic) way across languages. F0 showed a different effect in that Papuan Malay words have significantly higher mean F0 when repeated. Of the four studies that investigated F0 in addition to duration (Table 1), two studies found a significant decrease in F0 for second mentions (Jacobs et al., 2015; Lam, 2012). The results from the literature and the current study taken together suggest that F0 does not correlate consistently with repetition reduction. This outcome confirms a language-specific use of F0, rather than a (universal) inverse relationship between redundancy and F0, like the one that was found between redundancy duration.

As noted in section 2.6, the Multiple Source view on prominence (Watson, 2010) could explain why acoustic correlates do not behave uniformly. That is, duration and pitch are assumed to have different linguistic functions. In line with this view, duration is mainly affected by repetition, whereas F0 is the primary correlate of phrase intonation. In retrospect, this view may also explain the absence of F0 effects in the previous work on repetition reduction just mentioned (Fowler & Housum, 1987; Lam & Watson, 2010). However, this view does not necessarily explain why *opposite* effects of F0 and duration are found for repeated words in the current study. While this could be related to phrase intonation phenomena in Papuan Malay, these are largely unexplored to date.

Therefore, we have no explanation to offer for the higher F0 values observed in second mentions found in the current study.

Note that the higher F0 values in second mentions may have affected the results of our perception study. In earlier work, duration reduction alone was sufficient to decrease the intelligibility of second mentions (Fowler & Housum, 1987). Because in the current study both duration reduction and higher F0 was found for second mentions, this combination could have affected the intelligibility of second mentions in a different way. Whether this particular combination of diverging acoustic effects did indeed cancel out the loss of intelligibility in second mentions needs further investigation, and no conclusion can be offered on the basis of the current data alone.

The absence of consistent effects of word type in the current study re-confirms the necessity to disentangle processes related to the contextual meaning or informational value of words and processes related to the articulatory form of words. Repetition can coincide with changes in information status as reflected in the prosody of Germanic languages. Therefore, it has not always been clear to what extent the observed prosodic reduction can be attributed to repetition proper, a change from new to given information (e.g., Bard et al. 2000), or to a combination of the two. Some studies have managed to separate lexical repetition from information status (e.g., Lam & Watson, 2014) and this appears particularly fruitful in explaining the current results on Papuan Malay. It is possible that in Papuan Malay repetition effects on prosody are not related to the semantic value of words, but rather the mere phonetic repetition of words. That is, word type differences are expected when repetition reduction mainly results from differences in information value, which is supposedly low for function words and high for content words (Baumann & Winter, 2018). Crucially, none of the results in either the production or the perception experiment confirmed the hypothesis that repeated content words are more reduced than repeated function words. Given that there was no evidence to assume an intelligibility difference in the perception results, the perception experiment raises the question whether the observed shortening effects are indeed related to the informational value of the words. Rather, the effects of second mention shortening in the production data could be interpreted as a consequence of the speaker's auditory memory effects or mere lexical repetition (Jacobs et al., 2015; Lam & Watson, 2014). These effects could have occurred because the same (or similar sounding) mentions occurred in recent discourse, thus reflecting an articulatory (motor) benefit for the second mentions produced by Papuan Malay speakers, rather than a (perceivable) difference in information value. Although this reasoning is rather speculative, it would be compatible with two observations in the literature. First, it has been shown that duration mainly correlates with ease of articulation, not with (contextual) predictability (Watson, 2010). Second, preliminary work on Papuan Malay phrase prosody suggests that prosodic prominence plays a limited role in marking information status (Riesberg et al., 2018). To further support these potential explanations more research needs to be done on the functions of intonation patterns in Papuan Malay and specifically on the role of F0 in articulatory routines.

In sum, the current study shows that repetition reduction in prosody occurs in Papuan Malay word duration. The results of this study seem to be best explained by models that attribute different functions to different acoustic cues to prominence (Multiple Source view; Watson, 2010). In particular, it is essential to distinguish prosodic effects of repetition related to phonetic similarity from those related to meaningful context (i.e., information status, discourse structure). This distinction helps to explain the current results for Papuan Malay, and potentially generalizes to other languages.

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Supplemental material

Supplemental material for this article is available online.

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