A PRELIMINARY INVESTIGATION OF THE ACOUSTIC CONTEXT OF HOMOGRAPH PAIRS

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1. INTRODUCTION

The processing of lexically ambiguous words poses problems to both humans and machines. Much of the work in examining lexically ambiguous words or ambiguity in general has been of a psycholinguistic nature. There has been much work generated in this area over the past fifteen years. This paper attempts to examine some of the phonetic context surrounding lexically ambiguous words with the hope that this context will add further information that facilitates us as hearers and speakers in our disambiguation process. It is hoped further that some generalizations can be made from the results of this investigation, and by referring to previous research relating to the prosodics of ambiguous sentences, and prosodics in general.

2. PREVIOUS RESEARCH

While there has been little research in the area of acoustic environments surrounding lexical ambiguities, the research being discussed in this paper can be divided into two main focusses: language and speech. The work done in the area of lexical ambiguities that shall be considered to be of the language point of view is that of the psycholinguistic research. For years researchers have tried to discover how the mind processes ambiguities. It is thought that reaching an understanding on the processing of ambiguous items will aid in the understanding of how we process unambiguous items. On the other side of the coin is the research centering on the speech aspect of ambiguities. Little research has focussed on lexical ambiguities, with the majority of work being done in the area of syntactic ambiguities. Research in the area of prosodics, i.e. duration and intonation in particular, has reached a point today where there is enough information to develop models of speech timing and intonation for implementation on synthetic speech systems. One problem that all text-to-speech systems encounter is that of the treatment of ambiguities. Ambiguities of the syntactic nature must look to the discourse structure for solutions, while ambiguities of the lexical nature must look to the structure of the sentence, or syntax for a solution. While the work in psycholinguistics on lexical ambiguities has aided in understanding normal processing, it is hoped that the work done in speech technology on normal utterances will have a contribution to the correct handling of ambiguities for synthetic speech systems. In order to develop rules for natural sounding synthetic speech, or a theory of speech timing that accomodates lexically ambiguous words, more information must be obtained on the phonetic nature of lexical ambiguities.

2.1 Duration

Cooper and Paccia-Cooper (1980) have published the results of years of research in their investigations on durational aspects of syntax and speech. The majority of the work cited in their book tends to focus on syntactically ambiguous sentences, and the strategies that people incorporate in the prosodics for the disambiguation process. Cooper and Paccia-Cooper state that the lengthening that occurs in nouns over verbs can be attributed to their final position in major grammatical category phrases. Earlier work by Streeter (1978) and Lehiste *et al.* (1976) have provided the ground work in research in the area of duration in regards to the processing of syntactically ambiguous sentences. It was found by Lehiste *et al.* that the manipulation of duration was not successful in the disambiguation of sentences that contained deep-structure ambiguities. These are the sort that can be seen in sentences like *Visiting relatives can be a nuisance*. While these sentences are ambiguous at the level of deep structure, the two interpretations that can be made of the sentence involve lexical ambiguities of the word *visiting*. That is to say that in one interpretation the word is a verb and in the other the word is an adjective. Therefore while these sentences are ambiguous at the deep structure, what makes them ambiguous is the presence of lexically ambiguous words. Lehiste *et al.* claim that the disambiguation was unsuccessful because there was "no increase in the relevant interstress interval due to temporal manipulation." i.e. there were no pauses, and no durational adjustments that could be made based on the presence of different phrase boundaries. They conclude by saying that the disambiguation was unsuccessful when there is only one surface bracketing, as is the case with deep-structure (lexical) ambiguities. Although the bracketing is apparently the same in the two cases, in fact the structure must be different as the word *visiting* functions as a different part of speech in each case. Perhaps there is more going on in the prosodics than what was manipulated in their experiment. While it is not my intent to investigate this aspect of lexical ambiguities it is hoped that this preliminary study will bring up areas of further investigation that will assist in solving this problem.

2.2 Intonation

The results of a number of experiments with fundamental frequency contours in sentences have lead Cooper and Sorensen (1981) to the conclusion that while the declination represents a global trend of the fundamental frequency over a major syntactic constituent, fall-rise patterns are reflections of other types of syntactic boundaries. Other work in this area includes research with the declination line in English by O'Shaughnessy and Allen (1983), and Pierrehumbert (1979).

3. PURPOSE

The purpose of this study is to conduct a preliminary investigation on the acoustic context of lexically ambiguous words. Lexically ambiguous words, or homographs, are words which have the same spelling but have different meanings and often function as different parts of speech. While homographs are often pronounced the same, they may be pronounced differently. Little work has been done on the speech aspect of this linguistic phenomenon. Therefore the majority of research that shall be discussed relating to acoustic information shall be centered on aspects of prosodics associated with syntactically ambiguous sentences, and the prosodics of different lexical categories.

In particular, the items under investigation in this study are homograph pairs. Homograph pairs are items such as *trash* *can* , in which the individual words have different parts of speech, which can be determined from the structure of the sentence. For example, all the homograph pairs in this study can be either an adjective and a noun (AN), or a noun and a verb (NV). This can be seen in the following sentences:

Everyone agrees that the trash can smells awful.

Everyone agrees that the trash can smell awful.

Ten sentences were selected which contain homograph pairs of this nature. That is to say that there were five homograph pairs. The sentences selected came from a study by Frazier and Rayner (1987), in which they examined how people processed lexically ambiguous words as they read them, by monitoring their eye movements. A list of the sentences used in this study is supplied in the Appendix. The sentences were arranged in a randomized order in a list, with some filler sentences constructed that had a similar structure to the sentences containing the homograph pairs.

Homograph pairs provide the researcher in acoustics an interesting framework from which to examine supersegmental effects. The fact that the homograph pairs differ only in the syntactic environment provides an opposition from which one is able to test, or investigate, certain aspects of prosody: in particular, the effects of syntax on speech. All the phonological information of the words is the same in the AN and NV pairs. The only difference that one can test is syntactic. The same combination of speech sounds functions as an adjective in one case and a noun in another. Also confounded with this difference in lexical category is position in the syntactic constituent.

There has been much work in the area of phrase-final lengthening (Sorensen *et. al.* 1978, Cooper and Paccia-Cooper 1980, and Klatt 1979). One would expect that there should be different effects due to position in the phrase of the first word in the homograph pairs. That is to say that the syntactic boundaries differ for the pairs. In the AN pair there is an NP phrase boundary (indicated by a square bracket]), following the noun, the second word in the pair. A N]. However for the NV homograph pair, the NP phrase boundary follows the noun, which is the first word in the pair. N] V. As the adjective in the first pair is the same word, but with different meaning and lexical category, as the noun in the second pair, one would expect that the effects of phrase final position will be noticeable in the noun and not the adjective. In fact the phonological environment surrounding this word is identical. The sentences were constructed with the intent that the ordering of words is identical until after the last word of the homograph pair has been encountered.

4. PROCEDURE

The procedure adopted here is similar to that of Sorensen, *et. al.* (1978). Three speakers were selected on the criterion that they were male, within their mid-twenties in age, and had voices that did not exhibit peculiar voice qualities or intonation patterns. Herein the speakers shall be identified as CJ, PB and TH. All speakers had normal, or corrected to normal vision. Speakers were tested individually in a sound-proof room. Each speaker was presented with a typed list of the sentences as described above and filler sentences in a randomized order. They were instructed to practice each sentence until they felt that they could read it in a natural manner, without errors, and without placing emphatic stress on any particular word. The speakers were permitted to place stress on a word if they felt that this would make the meaning of the sentences clearer. This was decided upon to see if there was a particular strategy that was used by one speaker vs. the others, or by all speakers in general. Once a sufficient recording level was obtained, the subjects were then instructed to read each sentence out loud. The sentences were then recorded on a reel to reel magnetic tape. Data was then digitized using routines developed at the Centre for Speech Technology Research on the research tool Micro Speech Lab (MSL). The sampling rate was fixed at 10,000 samples per second, and the recording was filtered by a band-filter internal to the system at 70 Hz and 4000 Hz. The data resolution was set at 10 bits. This has been found to be adequate when examining speech for the purposes of investigating aspects of prosody.

5. ANALYSIS OF DATA

The sentences were captured using the method mentioned above. The homograph pairs were then isolated from these sentences and saved for further analysis. In the analysis of these homograph pairs, two aspects of prosody were examined: intonation and duration. It was decided not to examine the amplitude of the pairs, as the recording levels for each sentence were not constant, and in the capturing of the data, the level for input was adjusted in order to obtain the greatest resolution of the wave form. The durations of the homograph pairs were compared, as well as the pitch ranges of the pairs. The homograph pairs are identified as follows:

poor state is identified as PS(AN) or PS(NV) summer bears is SB(AN) or SB(NV) metal rings is MR(AN) or MR(NV) trash can is TC(AN) or TC(NV) military might is MM(AN) or MM(NV)

It is necessary to discuss the results in terms of what happened as a general trend as well as what was found in each pair, because each homograph pair was embedded in differing syntactic contexts. Two analyses of the duration were made. One was to determine if there was a difference in the mean duration of the differing homographs, across the speakers, the other was to determine if there were speaker differences. For each homograph pair, the mean duration was determined between the AN groups and the NV groups.

The homograph pairs were isolated from the sentences and the duration of the entire event, including pauses between words if there were any, was measured. In the MM sentences, judgements were made by the experimenter as to the vowel-consonant boundary between the homographs and the preceding words. Results of this analysis can be seen in Table 1.

A subsequent analysis of the durations of the individual words was made to see which word was the cause of this difference. In all cases, each word was measured from the same acoustic event. There were ten words in all, and of the six measurements of each word the measurement was taken from the same point. For example in the word STATE, the duration was determined to be from the onset of the frication to the end of voicing, or for the duration of /ste/. Results of these durational differences are given in Table 2.

It was generally found that the adjective noun pairs were longer than the noun verb pairs. The exceptions to this were the homograph pairs PS and MM. The significance of this shall be discussed in the subsequent section. The differences can be accounted for in terms of findings from previous research. The difference between the AN and the NV homograph pairs was calculated to discern if there was indeed any difference. For instance, when examining the homograph pair TRASH CAN, the duration of all six versions was calculated. Three speakers X two variations (AN vs. NV). A mean duration for the AN pair was found and a mean duration for the NV pair was found. The difference was taken, with the results that there is a trend for the AN pair to be longer than the NV pair.

An examination of the individual homographs was made in order to determine if there were effects due to phrase final position. In comparing a single homograph as it functions as an adjective vs. a noun, there were no conclusive results. That is to say that it was not a clear case that the noun was longer than the adjective. It could be safe to say that there was no significant effect due to phrase final lengthening. In fact in some homograph pairs the adjective was longer than the noun. This shall be discussed further in the discussion section. The results of the analysis of the individual speakers and the mean durations can be seen in Table 2.

When examining the intonation, or pitch contours of the homograph pairs, there was an analysis done by the algorithm in the program MSLPITCH to calculate the pitch. The pitch extraction algorithm functions by breaking the waveform into regular intervals (frames). Each frame was 20 msec long. It then examines each fame to determine and compare the time coordinates between the amplitude peaks. Once a period, or pitch value, has been found, this is compared with the values for the surrounding frames and a figure of merit is assigned as a measure of accuracy. As the algorithm is not precise in areas of voicing transition, and low energy data, a manual calculation was required on some areas of the speech signal. This was done by locating the segment of the wave form that had inaccurate pitch calculated. A mark was placed on an amplitude peak of the wave form, and the next peak was located. The pitch for that frame was then determined by calculating the inverse of the period. After the pitch contours for the homograph pairs were calculated, graphs were made to compare the pitch contours for each speaker in each condition.

As a preliminary measure of the data, the range for each homograph was calculated, and the mean pitch excursions for each of the ten homograph pairs was determined. This was then compared for AN vs. NV homograph pairs. The results of these measurements can be seen in Table 3. Generally the same pattern of results was obtained as for the duration. There were greater pitch ranges in the AN pairs than in the NV pairs. As part of the analysis of intonation, graphs of the pitch of the homograph pairs were made. This was done in order to see if there were any differences in the pitch contours in the homograph pairs. The significance of this and an explanation of the data shall be proposed in the subsequent section.

6. DISCUSSION

6.1 Duration

The results of the duration of AN-NV homograph pairs suggest that the AN pairs are of a longer duration than the NV pairs. The exceptions to this are the data for the pairs PS(AN) PS(NV) and MM(AN) MM(NV). The significance of the exceptions shall be discussed first, with a discussion of the implications of AN pairs longer than NV pairs saved until later. The sentence containing the PS(NV) homograph pair differed in its syntactic structure from the other NV sentences. *In many large nations, the poor state the rich deprive them of their rights*. In the other sentences, the verb form of the homograph subcategorizes for prepositional phrases, adjective phrases, verb phrases, and other phrasal categories. In the sentence above, the verb STATE subcategorizes for the largest syntactic constituent, S'. This contains two major boundaries before the next word is encountered, S' and S. Following the word state, there is a *that* deletion site. The syntactic structure surrounding the homograph pair is given below to illustrate the major boundaries.

Adjective Noun

NP[the ADJ[poor] N[state]] VP[V[deprives] ...]

Noun Verb

NP[the N[poor]] VP[V[state] S'[COMP[__] S[NP[the rich]]...]]]

This sentence pair shows the exception to the other pairs in that it is the only one (as well as MM(NV) and MM(AN)) that exhibits the verb as longer than the noun. This is interesting from the point of view of work done by Sorenson ***et. al.*** (1978) who found that nouns were typically longer than verbs. The only time that a verb was found to be longer in their study was when it occurred in final position in a phrase. In this example the verb is clearly at the beginning of a major grammatical category, and the noun is clearly at the end. The three speakers exhibit that the verb was longer than the noun, when the entire duration of the word was measured. It is interesting to note that when PB read the sentence, he automatically inserted the word *that* , and the duration of the word *state* still showed a difference in the length as a noun and a verb.

While it is clear that this is not much evidence to base any conclusions on, it would be interesting to investigate further. As the verb occurs before the largest grammatical category in English, S', with the occurance of *that* deletion, perhaps this exerts a greater effect on the lengthening of words than a other phrasal categories. It could be possible that there are more factors contributing to the lengthening of certain words than simply occurring at the end of a major syntactic boundary. It could in fact be a possibility that it is the presence of a following syntactic boundary that determines the lengthening, and not the fact that a word belongs at the end of a phrase. A further explanation for the lengthening of the word *state* as a verb is that it could be a lengthening to compensate for the *that* deletion immediately following. Work done by Cooper and Paccia-Cooper (1980) suggests that a word preceding the presence of *that* shows a small but significant lengthening. This lengthening was not found in the word immediately preceding a *that* deletion site. However, the nature of the word itself, in the study by Cooper and Paccia-Cooper, is a noun. The word *that* was deleted immediately following a noun. The phrase following the noun, even though it is a clause, is optional in their study. In the example being discussed here, the word in which lengthening occurs differs in two ways: it is a different part of speech (verb), and the word subcategorizes for the following constituent (S'). *State* subcategorizes for and therefore must be followed by an S'. This syntactic boundary might have more psychological relevance, and hence be more apt to be manifest in the speech.

In a more detailed examination of the durations of the individual homographs there were some interesting results. It was found that the word *summer* in the homograph pair SB, had the same mean duration as a noun and an adjective, but there were large subject differences. The mean durations can be found in Table 2. Because the duration of *summer* (A) is the same as *summer* (N) we can assume that there was no lengthening due to its place as the final member of the NP constituent. Would it be possible to conclude that the lengthening is then determined by the following syntactic boundary? More importantly, why does *summer* not lengthen in NP final position or if it does lengthen in NP final position, why does it lengthen in Adj position? Looking at the word *bears*, it was found that it is longer in NP final position, when functioning as a noun, than when functioning as a verb in initial position in the VP (for two out of three subjects only.) This is in accordance with previous findings. When a lexical item is in final position in a phrase, it is almost always followed by another phrase boundary, delimiting the beginning of another phrase. If one were to examine the individual duration of the words in the homograph pair SB, it would appear that the data from CJ are anomolous. If this data were rejected, then one could see the expected phrase-final lengthening of the noun *summer* as well as the noun *bears*.

A similar set of results was obtained for the sentences MM and TC. *Military* and *trash* were found to be the same duration as adjectives and nouns. It was found that the mean duration of CAN(V) was reduced by approximately fifty percent of the mean duration of CAN(N). While the reduction of this word, based on its position within a constituent, or based on its part of speech can account for some of the difference in length, most of this reduction must be attributed to the fact that CAN(V) functions as a modal in the sentence it was embedded. Functor words have been noted to be more reduced than other words as they carry very little semantic information that contributes to the meaning of the sentence. While the mean duration of the word CAN(V) was found to be reduced quite drastically, one speaker (PB) placed emphatic stress on the word. In this case, the duration was slightly longer than CAN(A). This did not seem to affect the overall mean duration for the word. This shall be discussed further in a section focussing on the effect of modals on the prosodics of the sentence.

6.2 Intonation

The same pattern of results obtained in examining the mean durations of the AN homographs against the NV homographs was obtained when examining the mean pitch ranges of these words. It was found that there was a greater pitch range found in the AN pairs than found in the NV pairs. This can be explained in terms of what is happening to the declination curve of the entire sentence. Declination curves are patterns of pitch ranges, that occur in sentences. The pattern of declination occurs in several languages. In English there has been much work in this area. There is a general trend for the pitch of a sentence to drift down near the end of an utterance. At major syntactic boundaries, the declination line can be reset, so that the following constituent begins at a higher pitch. Therefore one would expect that the pitch of a word in a homograph pair would be lower when it is at the end of a major syntactic boundary. This generally occurs to a noun when the homograph pair is an AN and not when it is an NV. The declination line is often reset at the end of an NP when in long utterances. It has been found that the pitch of the final word is higher in comparison to the first word when it is a V. That is to say that it has been found that the second word in the homograph pairs (N and V) is lower when it is at the end of a syntactic boundary than when it is not.

As was the case in examining the durations, there is an exception to this general finding. Again it is the homograph pair PS that deviates. In this pair, there is a greater pitch excursion in the NV pair than the AN pair. In examining the pitch contours of this homograph pair, several observations can be noted. CJ showed a clear fall-rise pattern on the word STATE(V). Cooper and Sorensen (1981) have noted that "a local fall-rise pattern of F0 accompaies the boundaries of clauses" and that "the magnitude of these fall-rise patterns was greater at strong boundaries." It can therefore be safe to say that, based on the results of the lengthening of the word STATE(V) and the pitch contour exibited by CJ, this speaker indicates that the boundary S' is a strong boundary. All subjects had a lower verb than a noun in the PS(NV) sentences. This is also an indicator of a strong syntactic boundary.

6.3 Modals

There has been some discussion in the literature on the effect of modals on the pitch contour of a sentence, and in particular on the continuation rise when one is given emphatic stress. O'Shaughnessy and Allen (1983) state that often the presence of a modal that carries contrastive information, i.e. information that is not redundant, there is a large slope of the pitch in the word. They state further than when there is emphasis on a particular word, it is realized in modals more than any other word class. In fact nouns and verbs are the lowest of the content words to carry emphasis, as they are the basic elements of the proposition. Of the ten sentences, there were two that contained a homographic word functioning as a modal. These are the MM(NV) and TC(NV). It has already been discussed that there was a lengthening of the modals when the speakers gave these words prominence in the sentences.

O'Shaughnessy and Allen (1983) make a distinction between two types of modal in their examination of the declination curve of English: 'restrictive' and 'nonrestictive.' Restrictive modals tend to be emphasized. *Might* is considered to belong to this class, while *can* is considered to belong to the nonrestrictive class of modals. They state that "restrictive modals received emphasis because they indicate the speaker's feeling about the proposition." Perhaps in the sense that PB emphasized *can* , it can be considered to be a restrictive modal in this situation. O'Shaughnessy and Allen state that it is important to keep in mind the fact that F0 emphasis is relative and one can expect a deemphasis of the main verb in sentences involving restrictive modals. In a later examination of these sentences, MM and TC, it was found that CJ and PB did exhibit a de-emphasis of the main verb when the restrictive modal was emphasized. The deemphasis has only been measured in terms of relative pitch height to the modal. In fact the following verb was of a lower pitch than the modal.

7. SPEAKER VARIATION

It is necessary to discuss on a more primary level the various strategies and speaker variations that occurred in this investigation. Of the three speakers, PB spoke with a rapid speech rate. Therefore it seemed that he used variations in the pitch to carry more information than variations in duration. In fact he exhibited the widest pitch range of all three speakers. It might be possible to conclude that the disambiguation of the homograph pairs by PB was effected more by a strategy based on pitch than duration.

In the analysis of the pitch ranges, TH had a relativeley low pitch with not as much excursion as PB. CJ when reading the sentence SB(NV) perhaps did not rehearse as much as the other sentences which he read. This data provides an anomoly to the other data in that paradigm. If this were to be thrown out, the trend would be that of the homograph pairs, the noun is longer than the adjective, and the noun is also longer than the verb.

7. CONCLUSION

Although this has been a preliminary, or investigative study on the acoustic environments surrounding homograph pairs, it seems clear that there is merit in this approach to the study of the effect of syntax on speech. The effect of syntax on speech is manifest in the prosody of an utterance. It seems duration and intonation sometimes work together in not only disambiguating utterances, but also at phrasal boundaries. Other research has supported the acoustic and psychological reality of syntactic boundaries on speech. This preliminary study supports some of these findings while also proposing that certain boundaries have a greater significance than others. The presence of clausal boundaries such as S and S' exerted a greater effect of lengthening on a previous word (V), than an effect of lengthening of a noun due to final position in a noun phrase. This seems to point to the idea that the durational adjustments that must and do occur in speech are more complex than have been previously suggested.

From the work done in this study it is clear that there are avenues of further investigation. One area that shall be pursued is the effect of *that* deletion from clauses that are optional vs. clauses that are subcategorized for by the verb, or noun.

APPENDIX

In my opinion, the military might be very dangerous in that country.

In my opinion, the military might of that country is very dangerous.

We all should have known that metal rings loudly, and for a long time.
We all should have known that metal rings are very strong.

Susan was extremely surprised that the summer bears no resemblance to the winter back home.
Susan was extremely surprised that the summer bears resemble the winter bears back home.

In many large nations, the poor state the rich deprive them of their rights.
In many large nations, the poor state deprives the rich states of their rights.

Everyone agrees that the trash can smell awful.
Everyone agrees that the trash can smells awful.

TABLES

Table 1. Mean durations of the differing homograph pairs, and their differences.

Homograph-Pair	Mean-Duration(sec)	Difference(sec)
PS(AN)	.611	.059
PS(NV)	.670	
SB(AN)	.777	.107
SB(NV)	.670	
MR(AN)	.710	.086
MR(NV)	.624	
TC(AN)	.604	.060
TC(NV)	.544	
MM(AN)	.684	.073
MM(NV)	.757	

Table 2. Durations of individual homographs by various speakers and the mean durations. (sec)

	MILITARY		MIGHT	
	A	N	N	V
CJ	.552	.566	.285	.384
PB	.390	.402	.189	.183
TH	.479	.456	.217	.189
	----	----	----	----
mean =	.474	.475	.230	.252

	METAL		RINGS	
	A	N	N	V
CJ	.370	.330	.510	.440
PB	.325	.315	.335	.225
TH	.324	.266	.369	.330
	----	----	----	----
mean =	.340	.304	.405	.332

	SUMMER		BEARS	
	A	N	N	V
CJ	.465	.347	.471	.478
PB	.326	.334	.382	.215
TH	.326	.422	.408	.202
	----	----	----	----
mean =	.372	.368	.420	.298

	POOR		STATE	
	A	N	N	V
CJ	.224	.186	.384	.405
PB	.193	.205	.253	.273
TH	.223	.216	.294	.345
	----	----	----	----
mean =	.213	.202	.310	.341

	TRASH		CAN	
	A	N	N	V
CJ	.345	.373	.286	.098
PB	.289	.275	.149	.189
TH	.340	.336	.161	.096
	----	----	----	----
mean =	.325	.328	.199	.128

Table 3. Pitch Ranges of the Homograph Pairs and the mean Pitch excursions. (Hz)

	POOR	STATE
	AN	NV
CJ	30	29
PB	26	51
TH	33	32
	--	--
mean =	30	37

	MILITARY MIGHT	
	AN	NV
CJ	26	24
PB	48	30
TH	25	21
	--	--
mean =	33	25

	SUMMER BEARS	
	AN	NV
CJ	29	27
PB	77	32
TH	40	30
	--	--
mean =	49	30

	TRASH CAN	
	AN	NV
CJ	46	28
PB	33	27
TH	19	12
	--	--
mean =	33	22

	METAL RINGS	
	AN	NV
CJ	19	26
PB	38	26
TH	17	12
	--	--
mean =	25	21

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