

Experiments on Accentuation and Focus Projection

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Hans-Christian Schmitz, Petra Wagner

schmitz@lingua.uni-frankfurt.de, pwa@ikp.uni-bonn.de

We describe five experiments on the accentuation of complex foci, i.e. of foci that consist of more than one word. The results of the experiments can be taken as evidence for the hypothesis of optimal accentuation according to which those words that are crucial for understanding an utterance are to be accentuated (cf. [Schmitz, 2005]). The results give clear counter-evidence against the nuclear stress rule according to which only the rightmost word of a complex focus must be accentuated. Finally, the results give interesting insights into what is called ‘the head-argument asymmetry’ of focus accentuation.

1 Introduction

The examples (1-4) are standardly used for demonstrating pragmatic and semantics effects of accentuation:

- (1) Whom did John introduce to Sue? — John introduced BILL to Sue.
- (2) To whom did John introduce Bill? — John introduced Bill to SUE.

Due to their different stress patterns, the declarative sentences of (1) and (2) have different usability conditions: The declarative sentence of example (1) can serve as an answer to the question of (1), but it cannot serve as an answer to the question of (2). Contrary, the declarative sentence of (2) can serve as an answer to the question of (2), but it cannot serve as an answer to the question of (1).

- (3) John only introduced BILL to Sue.
- (4) John only introduced Bill to SUE.

The sentences (3) and (4) are examples for semantic effects of accentuation: Because of their different stress patterns the sentences have different truth conditions.¹

¹ Cf. [Root, 1992].

Theories of focus² give a syntax-based explanation for semantic and pragmatic effects of accentuation: If two sentences have different stress patterns, they must have different syntactic structures. Because of their syntactic difference, the sentences can have different truth or usability conditions. The theoretical term “focus” is used for describing the syntactic difference: By accentuation, syntactic constituents are marked as foci. Sentences with different stress patterns therefore have different focus structures, and different focus structures give rise to different interpretations.

A complete theory of focus entails (a) a syntactic rule of focus assignment, (b) a phonological rule of focus accentuation and (c) a semantic or pragmatic rule of focus interpretation. Focus theories can differ with respect to any of these rules, and they can therefore state different empirical relations between stress patterns on the one hand and truth and usability conditions on the other hand. E.g., two theories of focus can differ in their phonological rule of focus accentuation. For a sentence with a given focus structure, they can therefore predict different stress patterns:

(5) What did John do? —

1. John [introduced Bill to SUE]_F.
2. John [introduced BILL to SUE]_F.

For the declarative sentences of the example (5) to be appropriate answers to the question under discussion, the entire verb phrase “introduced Bill to Sue” must be in focus. Note that the focus is a complex phrase which consists of more than one word. A phonological rule of focus accentuation determines which words of the verb phrase have to be accentuated in order to mark the whole phrase as a focus. Following the nuclear stress rule (NSR, [Chomsky and Halle, 1968]) only “Sue”, which is the rightmost word of the phrase, must bear an accent. Following alternative rules of [Gussenhoven, 1984], [Selkirk, 1995] and [Schwarzschild, 1999], “Bill” must also bear an accent. Due to different rules of focus accentuation, different predictions regarding the correct stress pattern are made. These predictions can be evaluated experimentally.

A theory of optimal accentuation (TOA) as developed in [Schmitz, 2005] explains the semantic and pragmatic effects of accentuation without referring to syntactic structures. The basic idea is as follows: Speech communication is often disturbed so that a listener may not recognize all words

² For an overview cf. [Rooth, 1996] and [Krifka, 1996].

that were uttered by a speaker. Nevertheless, the listener can understand the speaker's utterance as long as he recognizes the words that are crucial for understanding. (Not all words of an utterance are crucial for understanding.) By accentuating a word, the probability of its being recognized is raised. A speaker should therefore accentuate the crucial words.

A TOA claims that accentuation serves the mere pragmatic function of making an utterance well comprehensible. Semantic effects appear as epiphenomena of this pragmatic function: It depends on the dialogue context which words of an utterance are crucial for understanding and therefore have to be accentuated. Under the assumption that a speaker accentuates optimally, he presupposes constraints on the dialogue context by accentuation. If the truth conditions of the uttered sentence depend on the dialogue context, then the presupposition of context constraints can influence the truth conditions.

(6) What did John do? — John INTRODUCED BILL to SUE.

To understand the answer of example (6), the recipient has to recognize “introduced”, “Bill” and “Sue”. A TOA therefore predicts that these words have to be accentuated. This prediction is in conflict with the focus-theoretical predictions from example (5). The conflicting predictions can be experimentally evaluated.

Focus theories and a TOA make different predictions regarding the stress patterns of complex foci (multiple constituent foci). In this paper we describe experiments which were performed to evaluate the contradicting predictions. The results of our experiments are in favour of optimal accentuation.

We had to perform our experiments in German, since we only had German test persons (TPs) available. All TPs were undergraduate students of introductory courses at the former Institute of Communication Research and Phonetics at the University of Bonn. No TP took part in two of the experiments. The simple reason for the different numbers of TPs is that exactly these numbers of students attended the respective courses.

We assume that English and German do not behave differently in any interesting aspect regarding our experiments. We therefore assume that we would get similar results if we performed the experiments in English.

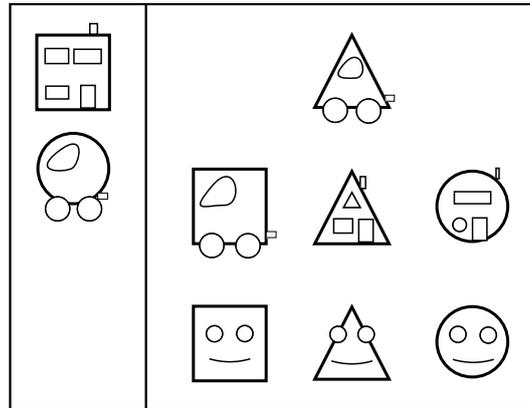


Figure 1: reference world for the examples (7-11)

2 Context Dependency of Accentuation

Following the nuclear stress rule (NSR), the accentuation of a focus does not depend on the utterance context. It is always sufficient to accentuate only the final, i.e. rightmost word of a phrase in order to mark the whole phrase as a focus.

(7) Only the square [HOUSE]_F is in the left field.

(8) Only [the square HOUSE]_F is in the left field.

In the examples (7) and (8), the noun “house” is accentuated. By the accent on “house”, either the single noun “house” or the entire determiner phrase “the square house” is marked as a focus. The determination of the focus influences the interpretation of the sentence: With the toy world of figure (1) as a reference world, the sentence (7) is true but the sentence (8) can be false.

Can be false? Why not “is false”? — The focus-theoretical interpretation of (8) is to be made precise in the following way: Let a set of alternative objects for the square house be given. Sentence (8) means that exactly one member of the alternative set, namely the square house itself, is in the left field.³ The determination of the presupposed alternative set can be context-dependent:

³ Cf. [Rooth, 1992] and [Krifka, 1992].

(9) What is in the left field? —

Only [the square HOUSE]_F is in the left field.

(10) Which square is in the left field? —

Only [the square HOUSE]_F is in the left field.

If the question in example (9) is under discussion, then all nine objects from the reference world depicted in figure (1) are proper alternatives of the square house. The answer that only the square house is in the left field is false since also the round car is in the left field. However, if the question from example (10) is under discussion, then only the three squares from the reference world are proper alternatives to the square house. The square house is the only square which is in the left field. Therefore the answer, that only the square house is in the left field is true.

If the NSR is right, then (a) focus marking by accentuation can be ambiguous and (b) the accentuation of a given focus does not depend on the utterance context.

Following a TOA, “Only the square HOUSE is in the left field” is not ambiguous. The utterance of the sentence with the only accent on “house” triggers the presupposition that the question is under discussion which square is in the left field. The sentence has to be interpreted as an answer to this question. As such it means that there is no other square except the square house in the left field. The interpretation is equivalent to the focus-theoretical interpretation of the examples (7) and (10). In order to generate the focus-theoretical interpretation of example (9), it must be presupposed that it is under discussion what in general is in the left field – not only *which square* is in the left field. In order to trigger the presupposition of this question, one has to accentuate both the the adjective “square” and the noun “house”:

(11) What is in the left field? —

Only the SQUARE HOUSE is in the left field.

A TOA explains the different meanings of “Only the square house is in the left field” by referring to different utterance contexts. The different utterance contexts demand different stress patterns: If the sentences are to be interpreted differently, they have to be accentuated differently.

The NSR and a TOA have different hypotheses regarding the context-dependency of accentuation. In particular, they make different predictions

regarding the correct accentuation of the declarative sentence in the examples (10) and (11). In this section, we describe three experiments which we performed in order to investigate the context-dependency of accentuation.

2.1 Background Questions

A TOA and a focus theory including the NSR predict different stress patterns for the answers of example (10) and (11) respectively. Which theory is right?

2.1.1 Experiment

39 test persons (TPs) – among them 28 native speakers (NSs) and 11 non-native speakers (NNSs) of German – take part in the first experiment. The TPs are confronted with dialogue situations and two recordings of each the four question-answer dialogues (12-15):

(12) (*What's in the left field?* —
Only the square house is in the left field.)

1. Was ist im linken Feld? —
 Nur das quadratische HAUS ist im linken Feld.
2. Was ist im linken Feld? —
 Nur das QUADRATISCHE HAUS ist im linken Feld.

(13) (*Which triangle in the left field?* —
Only the triangular car is in the left field.)

1. Welches Dreieck ist im linken Feld? —
 Nur das DREIECKIGE AUTO ist im linken Feld.
2. Welches Dreieck ist im linken Feld? —
 Nur das dreieckige AUTO ist im linken Feld.

(14) (*Which square is in the left field?* —
Only the square house is in the left field.)

1. Welches Quadrat ist im linken Feld? —
 Nur das quadratische HAUS ist im linken Feld.
2. Welches Quadrat ist im linken Feld? —
 Nur das QUADRATISCHE HAUS ist im linken Feld.

(15) (*What's in the left field?* —

Only the triangular car is in the left field.)

1. Was ist im linken Feld? —

Nur das DREIECKIGE AUTO ist im linken Feld.

2. Was ist im linken Feld? —

Nur das dreieckige AUTO ist im linken Feld.

All dialogues consist of a question and an answer. In two dialogues (12, 15) a question without a restrictor – *What's in the left field?* – is asked. In the other two dialogues (13, 14), a question with a restrictor – *Which square/ triangle is in the left field?* – is asked. Each dialogue is recorded twice. The two recordings differ only with respect to the stress pattern of the answer: The grammatical subjects of the answer sentences are determiner phrases (DPs) consisting of a determiner, an adjective and a noun. In one recording, only the noun is accentuated. In the other recording, the adjective is also accentuated. (In the answers of the dialogues (12-15), the accentuated words are set in capital letters.)

For each dialogue, the TPs are asked which of the recorded answers is the ‘better’, more appropriate answer. The experiment is a forced choice experiment: The TPs have to decide for one recording, i.e. for one stress pattern. Each TP evaluates the accentuation of two answers following a question without a restrictor and of two answers following a question with a restrictor. We therefore get 78 judgements from 39 TPs on the proper accentuation of answers following a question without a restrictor, and we get 78 judgements on the proper accentuation of answers following a question with a restrictor.

Experiments on the accentuation of focus operators (cf. [Schmitz, 2006]) have shown that the TPs can be influenced by the order in which the dialogue-recordings are played. To compensate for such an unwanted influence, we vary the order of presentation: For two dialogues (12, 14), we first play the recording with an accent only on the noun, and then we play the recording with accents on the adjective and the noun. For the other two dialogues (13, 15), we first play the recording with accents on the adjective and the noun, and then we play the recordings with an accent only on the noun.

Together with the dialogue-recordings we present the reference worlds depicted in figure (2). In each world there are two fields, a left field and a right field. Nine objects are in these fields. The objects have two kinds of distinctive properties: They are either cars, houses or faces, and they are either squares, triangles or circles. Moreover, they are either in the left

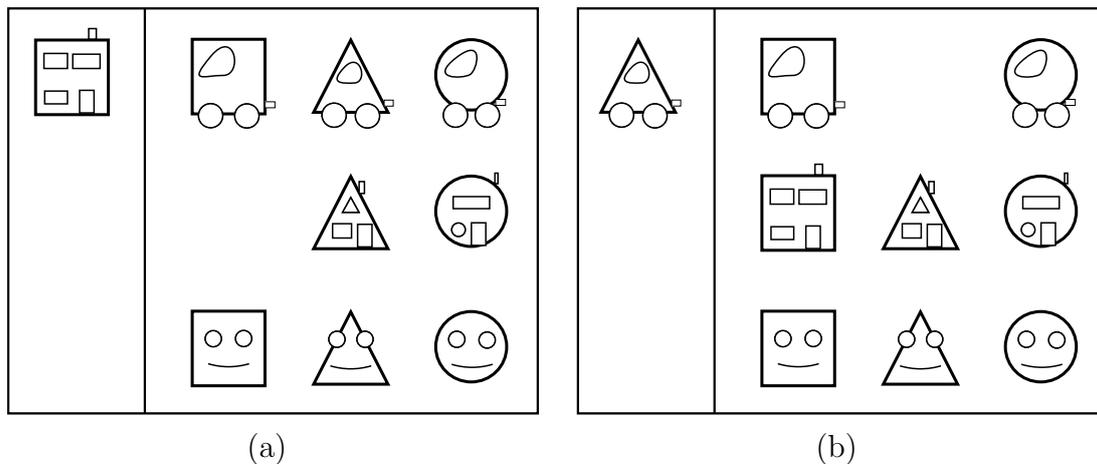


Figure 2: reference worlds for the first experiment

field or in the right field. In the left world of figure (2) only the square house is in the left field. In the right world, only the triangular car is in the left field. The left world is presented together with the dialogues (12) and (14), the right world is presented together with the dialogues (13) and (15). We tell the TPs that the questioner knows which objects exist but that he does not know in which fields the objects are. The answerer has complete knowledge of the reference worlds. He shall inform the questioner adequately.

By specifying reference worlds for the test dialogues, we prevent the TPs from presupposing non-controlled circumstances for the evaluations of the dialogue recordings. Thus, we constitute controlled test conditions.

Following the NSR, focus accentuation is not context-dependent. There should be no correlation between the question types and the TPs' preferences regarding the accentuation of the answers: In all answers, only the noun of the subject-DP has to bear an accent. The adjective must never be accentuated. The NSR therefore predicts that most TPs always prefer the answer recordings in which only the noun is accentuated.

A TOA makes the hypothesis that in answers that follow a question without a restrictor – *What's in the left field?* – not only the noun but also the adjective has to be accentuated. The theory predicts that in these answers the TPs prefer accents on both adjective and noun. For the stress patterns of the answers that follow a question without a restrictor – *What's*

		accentuation			
		adjective and noun		only noun	
question with restrictor	total	23	(29.5%)	55	(70.5%)
	NSs	18	(32.1%)	38	(67.9%)
	NNSs	5	(22.7%)	17	(77.3%)
question without restrictor	total	52	(66.7%)	26	(33.3%)
	NSs	37	(66.1%)	19	(33.9%)
	NNSs	15	(68.2%)	7	(31.8%)

Table 1: results of the first experiment

in the left field? – the theory makes the same predictions as the NSR: Most TPs will prefer the recording in which only the noun is accentuated. Contrary to the NSR, a TOA claims that accentuation is context-dependent. The theory predicts a clear correlation between question types and the TPs’ preferences regarding the accentuation of the answers.

2.1.2 Results

The results of the experiment are given in table (1): For answers to questions with a restrictor, most TPs (70.5%) prefer that only the noun is accentuated. This was predicted both by the NSR and by a TOA. For answers to questions without a restrictor, most TPs (66.7%) prefer accents on the adjective and on the noun of the subject-DP. This was predicted by a TOA, but it is against the NSR-prediction.

Moreover, the data show a clear correlation between the question types and the TPs’ accentuation preferences. The one-sided t-test for comparing the null hypothesis (NSR: *There is no correlation of question types and accentuation preferences*) with the alternative hypothesis (TOA: *Accents on the adjectives are preferred in answers that follow a question without a restrictor*) yields a **p-value of 2.877e-06**.⁴

⁴ The p-value for the native speakers alone is 0.0003019. The p-value for the non-native speakers alone is 0.002884.

2.1.3 Discussion

The data of the first experiment clearly corroborate the TOA-hypothesis. Note that the TOA-hypothesis does not make any claims on the acoustic realization of the accents. Acoustic correlates of accents can be a longer duration, a higher intensity, an extreme value of the pitch and a high spectral tilt. An accent need not be realized by all these means – e.g., a word can be perceived as accentuated even though it does not correlate with an extreme pitch movement. This means that if in our test examples both the adjective and the noun are accentuated there is no formal necessity that both accents are realised with *pitch* accents, although in our recordings they are pitch maxima on all accentuated words (i.e. both the adjective and the noun).⁵

2.2 New Words

Next, consider the following dialogues (17) and (18) together with the reference worlds depicted in figure (3):

(17) Which circle is in the left field? —
Only [the round car]_F is in the left field.

(18) What is in the left field? — Only [the round car]_F is in the left field.

Following the NSR, in both answers only the noun “car” has to be accentuated. Following a TOA, the correct accentuation is context-dependent: In the answer of dialogue (17) only the noun “car” has to be accentuated,

⁵ One might object that the specification of the foci in the answers to the question with a restrictor was not correct. Instead of the entire subject-DP, only the noun had to be focussed:

(16) Which square is in the left field? — Only the square [HOUSE]_F is in the left field.

Reply: (a) The crucial data are the TPs’ evaluation of the answers to the questions without a restrictor. There is no dispute that in these answers the entire subject-DP has to be focussed. (b) The focus of the answer sentence in example (16) is first associated with “only” and secondly serves the function of establishing the question-answer congruence. If only “house” is focussed, then the question of (16) has to be interpreted in the sense of “Of what kind is the square in the left field?” Under this interpretation, the questioner asks for a property, not for an object. Since the question can be answered by naming an object – e.g. “Object 1 is in the left field” –, this interpretation is not convincing.

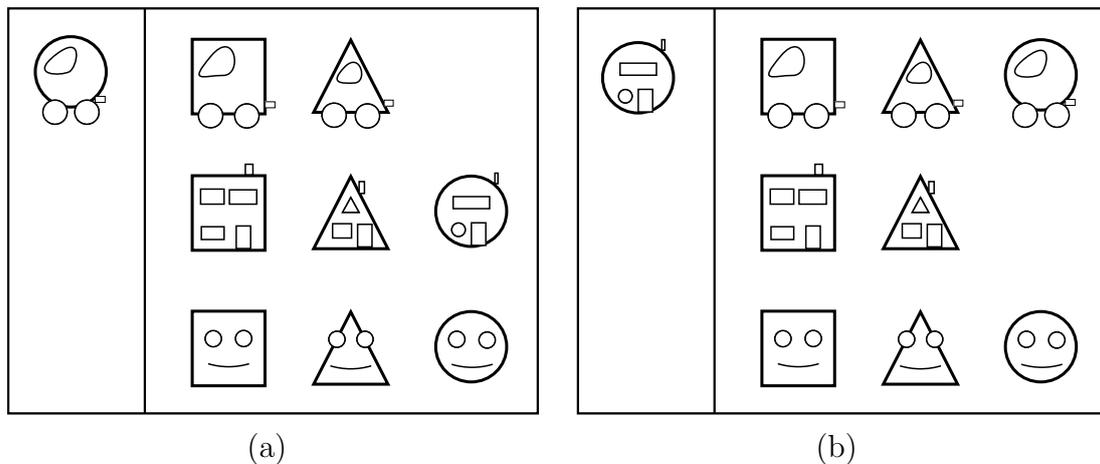


Figure 3: reference worlds for the second experiment

but in the answer of dialogue (18) also the adjective “round” has to be accentuated.

It might be that both the NSR and a TOA are wrong. One could claim the hypothesis that in both dialogues – i.e. irrespective of the question under discussion – the adjective “round” must be accentuated. A justification for this hypothesis could be that the adjective “round” does not occur in either of the questions. The adjective is therefore *new* in both answers, and new words must be accentuated.

2.2.1 Experiment

Let’s evaluate the competing hypothesis: We repeat the first experiment (section 2.1) with slightly changed dialogues and reference worlds. 27 TPs – 21 NSs, 6 NNSs – take part in this experiment. We play two recordings of each of the following dialogues (19-22). While playing the recordings of (19) and (22), we show the left picture of figure (3) as a reference world. While playing the recordings of (20) and (21), we show the right picture of figure (3) as a reference world.

(19) (*What’s in the left field? — Only the round car is in the left field.*)

1. Was ist im linken Feld? —

Nur das runde AUTO ist im linken Feld.

2. Was ist im linken Feld? —

Nur das RUNDE AUTO ist im linken Feld.

(20) (*Which circle is in the left field? —*

Only the round house is in the left field.)

1. Welcher Kreis ist im linken Feld? —

Nur das RUNDE HAUS ist im linken Feld.

2. Welcher Kreis ist im linken Feld? —

Nur das runde HAUS ist im linken Feld.

(21) (*What's in the left field? — Only the round house is in the left field.*)

1. Was ist im linken Feld? —

Nur das RUNDE HAUS ist im linken Feld.

2. Was ist im linken Feld? —

Nur das runde HAUS ist im linken Feld.

(22) (*Which circle is in the left field? —*

Only the round car is in the left field.)

1. Welcher Kreis ist im linken Feld? —

Nur das runde AUTO ist im linken Feld.

2. Welcher Kreis ist im linken Feld? —

Nur das RUNDE AUTO ist im linken Feld.

Again, all dialogues consist of a question and an answer. In two dialogues (19, 21), a question without a restrictor – *What's in the left field?* – is asked. In the other two dialogues (20, 22), a question with a restrictor – *Which circle is in the left field?* – is asked. The recordings of each dialogue differ only in to the stress pattern of the answer. In one recording only the noun of the subject-DP is accentuated, and in the other recording both the adjective and the noun are accentuated. For each dialogue, the TPs are asked which is the ‘better’, more appropriate answer. The experiment is a forced choice experiment: The TPs have to decide for one recording, i.e. for one stress pattern.

2.2.2 Results

The results of the experiment are given in table (2): For answers to questions with a restrictor (20, 21), most TPs (59.3%) prefer that only the noun is accentuated. This was predicted by the NSR and by a TOA but

		accentuation			
		adjektive and noun		only noun	
question with restrictor	total	22	(40.7%)	32	(59.3%)
	NS	16	(38.1%)	26	(61.9%)
	NNS	6	(50%)	6	(50%)
question without restrictor	total	38	(70.4%)	16	(29.6%)
	NS	32	(76.2%)	10	(23.8%)
	NNS	6	(50%)	6	(50%)

Table 2: results of the second experiment

not by the new, alternative hypothesis. For answers to questions without a restrictor (19, 22), most TPs (70.4%) prefer that the adjective and the noun are accentuated. This was predicted by a TOA and by the new, alternative hypothesis, but not by the NSR.

The data show a clear correlation between the question-types and the accentuation preferences. The one-sided t-test for comparing the null hypothesis (NSR, new hypothesis: *There is no correlation between question type and accentuation preferences*) with the alternative hypothesis (TOA: *An accent on the adjective is preferred in answers that follow a question without a restrictor*) yields a **p-value** of **0.001735**. The data are highly significant and corroborate the TOA-hypothesis.⁶

2.2.3 Discussion

The results of the second experiment are clearly in favour of a TOA. The new, alternative hypothesis does not seem to be very probable.

⁶ The data remain significant when only the native speakers' preferences are evaluated: The t-test yields a p-value of 0.0004124. The data are not significant when only the non-native speakers' preferences are evaluated: The t-test yields a p-value of 0.6579. Since we had only 6 non-native speakers, this result is not astonishing. It is not very probable that such a low number of TPs yields a low p-value.

2.3.1 Experiment

Let's test this assumption with an experiment: Again, we repeat the first experiment with adjusted dialogues and reference worlds. We play two recordings of each of the following dialogues (25), and we show the pictures of figure (4) as reference worlds for the dialogues:

- (25) (*Which circle is in the left field? —*
Only the round car is in the left field.)
1. Welcher Kreis ist im linken Feld? —
 Nur das runde AUTO ist im linken Feld.
 2. Welcher Kreis ist im linken Feld? —
 Nur das RUNDE AUTO ist im linken Feld.
- (26) (*Which square is in the left field? —*
Only the square house is in the left field.)
1. Welches Quadrat ist im linken Feld? —
 Nur das QUADRATISCHE HAUS ist im linken Feld.
 2. Welches Quadrat ist im linken Feld? —
 Nur das quadratische HAUS ist im linken Feld.
- (27) (*Which square is in the left field? —*
Only the square car is in the left field.)
1. Welches Quadrat ist im linken Feld? —
 Nur das quadratische AUTO ist im linken Feld.
 2. Welches Quadrat ist im linken Feld? —
 Nur das QUADRATISCHE AUTO ist im linken Feld.
- (28) (*Which circle is in the left field? —*
Only the round house is in the left field.)
1. Welcher Kreis ist im linken Feld? —
 Nur das RUNDE HAUS ist im linken Feld.
 2. Welcher Kreis ist im linken Feld? —
 Nur das runde HAUS ist im linken Feld.

38 TPs – 29 NSs, 9 NNSs – take part in this experiment. As in the other experiments, the TPs have to evaluate the stress patterns of the answers. For each dialogue, they decide which is the ‘better’, more appropriate stress pattern. As before, the experiment is a forced choice experiment.

		accentuation			
		adjektive and noun		only noun	
„Kreis“ – „rund“	total	42	(55.3%)	34	(44.7%)
	NS	28	(48.3%)	30	(51.7%)
	NNS	14	(77.8%)	4	(22.2%)
„Quadrat“ – „quadratisch“	total	24	(31.6%)	52	(68.4%)
	NS	16	(27.6%)	42	(72.4%)
	NNS	8	(44.4%)	10	(55.6%)

Table 3: results of the third experiment

2.3.2 Results

The results of the experiment are given in table (3): The overall tendency to prefer an accent on “round” (*runde*) is significantly stronger than the overall tendency to prefer an accent on “square” (*quadratische*): 55.3% vs. 31.6%. The one-sided t-test for comparing the null hypothesis (*There is no correlation between the choice of the adjective and the accentuation preferences*) and the alternative hypothesis (*The tendency to prefer an accent on “round” is stronger than the tendency to prefer an accent on “square”*) yields a **p-value** of **0.00261**.⁷ The data are highly significant regarding a correlation between the choice of the adjective and the accentuation preferences.

The non-native speakers show a significantly stronger tendency to prefer an accent on “round” (*runde*) than the native speakers. The one-sided t-test for comparing the null hypothesis (*NSs and NNSs have the same preferences regarding the accentuation of “round”*) and the alternative hypothesis (*NNSs prefer an accent on “round” while NSs do not*) yields a **p-value** of **0.001243**. The non-native speakers do not show a significantly stronger tendency to prefer an accent on “square” (*quadratische*) than the native speakers. The **p-value** for comparing the respective hypotheses on the accentuation of “square” is **0.1462**.

⁷ The p-value for the native speakers alone is 0.01737. The p-value for the non-native speakers alone is 0.429.

2.3.3 Discussion

Following a TOA, neither the adjective “square” (*quadratische*) nor the adjective “round” (*runde*) has to be accentuated in the test examples. Both adjectives are not crucial for understanding the answers. The listener can compensate for their non-recognition by reconstruction their semantic value out of the context. The tendency of the TPs to prefer an accent on “round” rather than an accent on “square” might be explained by different ‘degrees of givenness’: Probably, the fact that one can compensate for the non-recognition of “round” is not as trivial as the fact that one can compensate for the non-recognition of “square”. For non-native speakers it might be even harder to realize the reconstructability of “round”. This was an explanation why the non-native speakers prefer an accent on “round” significantly more often than the native speakers.

2.4 Conclusions

The results of the three experiments from section (2) falsify the nuclear stress rule:

- It is not always sufficient to accentuate only the final, i.e. rightmost word of a focus.
- Focus accentuation is context-dependent: A declarative sentence with a given focus structure can serve as an answer to different, non-equivalent questions. Which of these questions is under discussion has no influence on the focus structure of the declarative sentence. However, the experimental data show that the choice of the question under discussion has an influence on which words of the focus have to be accentuated. This means that the accentuation of a focus depends on the utterance context.

3 Head-Argument Asymmetry

The accentuation of foci is context-dependent. If one wishes to maintain that stress patterns are grammaticalised, it is not sufficient to identify the foci in the syntactic structure of a sentence; additionally it is necessary to identify which words in the foci must be accentuated.

For this purpose, [Selkirk, 1995] introduces the technical feature *f*. Selkirk defines rules for the assignment of the *f*-feature, specifies the relation

between foci and expressions that carry the f -feature and determines which of these expressions are to be accentuated:

1. The feature f can be freely assigned to any word. We have a collection of rules of the following schema, in which the variable C' can be replaced with the symbol for any word class:

$$[C']_f \rightarrow C'$$

Each word that is assigned the f -feature is accentuated. If in the sentence “Only the square house is in the left field” both the words “square” and “house” must be accentuated, they must both be assigned the f -feature:

(29) Only the [SQUARE] _{f} [HOUSE] _{f} is in the left field.

If in the same sentence only the word “house” must be accentuated, only this word should receive the f -feature:

(30) Only the square [HOUSE] _{f} is in the left field.

2. The f -feature can be projected from the internal argument of a phrase to the phrase head. The determiner “the” is the head of the DP “the square house”, “house” is an argument of the head, and “square” is a modifier of “house”. The f -feature can be projected from the noun “house” to the determiner “the”:

(31) Only [the] _{f} [SQUARE] _{f} [HOUSE] _{f} is in the left field.

(32) Only [the] _{f} square [HOUSE] _{f} is in the left field.

A word that is assigned an f -feature through projection – here “the” – is not accentuated.

3. From the head of a phrase the f -feature can project to the entire phrase:

(33) Only [[the] _{f} [SQUARE] _{f} [HOUSE] _{f}] _{f} is in the left field.

(34) Only [[the] _{f} square [HOUSE] _{f}] _{f} is in the left field.

4. A focus is an expression that carries the f -feature and that is not syntactically dominated by any other expression that carries an f -feature. In the sentences (33) and (34) it is the DP “the square house” that is focused:

(35) Only $[[\text{the}]_f [\text{SQUARE}]_f [\text{HOUSE}]_f]_F$ is in the left field.

(36) Only $[[\text{the}]_f \text{square} [\text{HOUSE}]_f]_F$ is in the left field.

Selkirk’s rules make different stress patterns possible for the focus “the square house”; the focus can be pronounced either with or without accentuating the adjective “square”.

It is the discourse context that determines whether “square” must be accentuated, i.e., whether it must carry the f -feature. According to Selkirk the adjective “square” must carry the f -feature and be accentuated if it is contextually ‘new’; if on the other hand it is contextually ‘given’, it cannot carry the f -feature and cannot be accentuated:

1. Every expression that carries the f -feature and that is not a focus, is contextually *new*.
2. Every expression that does not carry the f -feature, is contextually *given*.
3. Every focus is contextually *new* or *given*.

The distinction between contextually given and new expressions is not always precisely defined in the literature. Let us follow [Halliday, 1967]:⁸ An expression is contextually new if it cannot be deduced from the previous discourse or from the broader situation, if it contrasts to a previously uttered or somehow derivable alternative, or if it replaces the *wh*-element of a question under discussion. Otherwise it is given. In the answer to the question what is in the left field, the adjective “square” is new, and must therefore be f -marked and accentuated:

(37) What is in the left field? —

Only $[[\text{the}]_f [\text{SQUARE}]_f [\text{HOUSE}]_f]_F$ is in the left field.

In the answer to the question which square is in the left field, the adjective “square” is given; it cannot be f -marked nor accentuated:

(38) Which square is in the left field? —

Only $[[\text{the}]_f \text{square} [\text{HOUSE}]_f]_F$ is in the left field.

⁸ Cf. also [Prince, 1981] and [Schwarzschild, 1999]. [Schwarzschild, 1999] gives a precise definition of “given”.

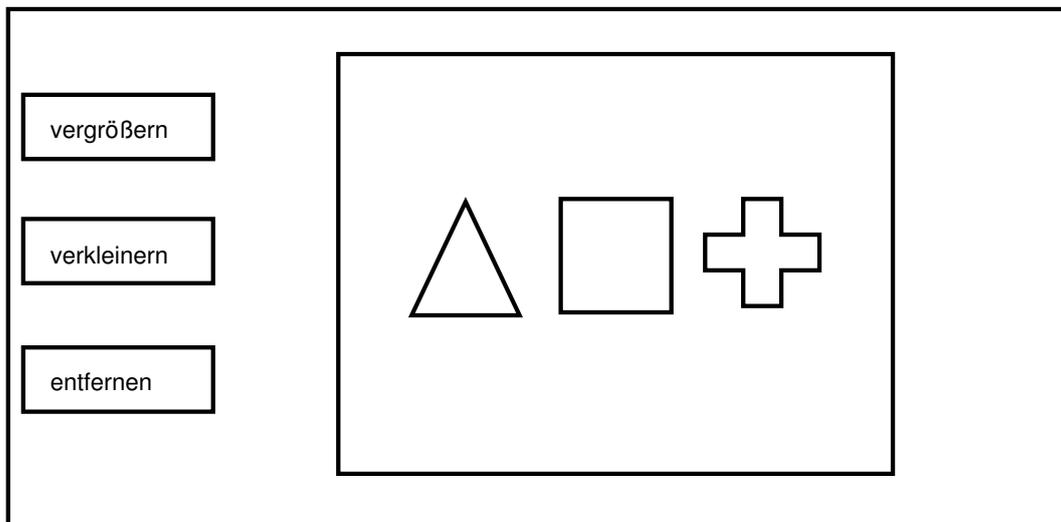


Figure 5: reference world for example (39) and for the fourth experiment, part 1

That is, according to Selkirk, the accentuation of the focus “the square house” depends on the question context. Selkirk predicts the same stress patterns for the answer sentences of examples (37) and (38) as a TOA.

However, Selkirk does not always predict the same stress patterns as a TOA: In general, Selkirk’s theory states that the internal arguments of a phrase can receive the f -feature only through free assignment; if they carry the feature, they must be accentuated. The head of a phrase can receive the f -feature also through projection; that is, a head that carries the f -feature does not always have to be accentuated. This means that there is a general asymmetry between the accentuation of contextually new, f -marked heads and new, f -marked arguments of a phrase (a so-called *head-argument asymmetry*). Optimal accentuation does not entail such an asymmetry. As a result, accentuation predictions of optimal accentuation differ regularly from Selkirk’s. Consider the following example (39) together with the reference world depicted in figure (5):

(39) What does Peter do? —

1. Peter $[[\text{deletes}]_f [[\text{the}]_f [\text{SQUARE}]_f]_f]_F$.
2. Peter DELETES the SQUARE.

Figure (5) shows a gameboard with three objects: a triangle, a square and a cross. The objects can be manipulated with the buttons on the

left in three different ways: they can be enlarged (*vergrößern*), reduced (*verkleinern*) or deleted (*entfernen*). That is, altogether there are nine possible actions: enlarging/ reducing/ deleting the triangle/ square/ cross. The questioner of example (39) asks which action Peter takes.

Following Selkirk, the verb “deletes” and the noun “square” are both contextually new in the answer of example (39) and therefore have to be *f*-marked.⁹ The *f*-feature is freely assigned to the noun “square”; it therefore has to be accentuated. From “square” the *f*-feature is projected to the head “the” of the DP “the square”; from “the” it is projected to the entire DP which is an internal argument of the verb “deletes”. The *f*-feature is projected from the DP to the verb (head) and from the verb to the entire VP. The VP becomes a focus. “Delete” is contextually new, but since it can receive the *f*-feature by projection it does not have to be accentuated.

Following a TOA, the recognition of the verb “delete” is crucial for the understanding of the entire answer. The verb therefore has to be accentuated.

A focus theory *à la* Selkirk and a TOA predict different stress patterns for the answer of example (39). Which theory is right?

([Schwarzschild, 1999] criticises Selkirk’s rule system. He shows that the rules of contextual linking are *ad hoc* and lead to partially incorrect predictions. Schwarzschild proposes an alternative rule system, according to which *f*-marking is less strongly syntactically restricted. In his model, though, there is still a head-argument asymmetry – unlike in a TOA. This may in fact be an important reason for him to adhere to the idea of syntactic *f*-marking: “We stop short of eliminating *f*-marking altogether, but this move is strongly suggested” ([Schwarzschild, 1999], 143). We do not need to illustrate Schwarzschild’s rule system here. For example (39), Schwarzschild predicts the same stress pattern as Selkirk, which differs from the one optimal accentuation predicts; the discussion of the rule system applies equally to his system.

[Gussenhoven, 1984] defines a differently motivated rule (system), the Sentence Accent Assignment Rule. According to his rule, there is also an asymmetry similar to the head-argument asymmetry which is not entailed by a TOA. The results of experiments whether there is such an asymmetry

⁹ The VP “deletes the square” and the DP “the square” are also new and have to be *f*-marked, but this is not relevant here. Let us also ignore the question whether the determiner “the” has to be considered as new or not.

and of what kind this asymmetry is also apply to the evaluation of his rule.)

3.1 Perception

We perform a perception experiment to evaluate the competing hypotheses on the accentuation of examples like (39). The experimental setup is similar to that of the experiments described in section (2.1-2.3).

3.1.1 Experiment

We play two recordings from each of the following question-answer dialogues (40-47):

(40) (*What does Peter reduce? — Peter reduces the square.*)

1. Was verkleinert Peter? —
Peter VERKLEINERT das QUADRAT.
2. Was verkleinert Peter? — Peter verkleinert das QUADRAT.

(41) (*What does Jan do? — Jan enlarges the triangle.*)

1. Was macht Jan? — Jan vergrößert das DREIECK.
2. Was macht Jan? — Jan VERGRÖßERT das DREIECK.

(42) (*What does Otto do? — Otto deletes the cross.*)

1. Was macht Otto? — Otto ENTFERNT das KREUZ.
2. Was macht Otto? — Otto entfernt das KREUZ.

(43) (*What does Jan enlarge? — Jan enlarges the triangle.*)

1. Was vergrößert Jan? — Jan vergrößert das DREIECK.
2. Was vergrößert Jan? — Jan VERGRÖßERT das DREIECK.

(44) (*What does Frank do? — Frank reduces the triangle.*)

1. Was macht Frank? — Frank verkleinert das DREIECK.
2. Was macht Frank? — Frank VERKLEINERT das DREIECK.

(45) (*What does Otto delete? — Otto deletes the cross.*)

1. Was entfernt Otto? — Otto ENTFERNT das KREUZ.
2. Was entfernt Otto? — Otto entfernt das KREUZ.

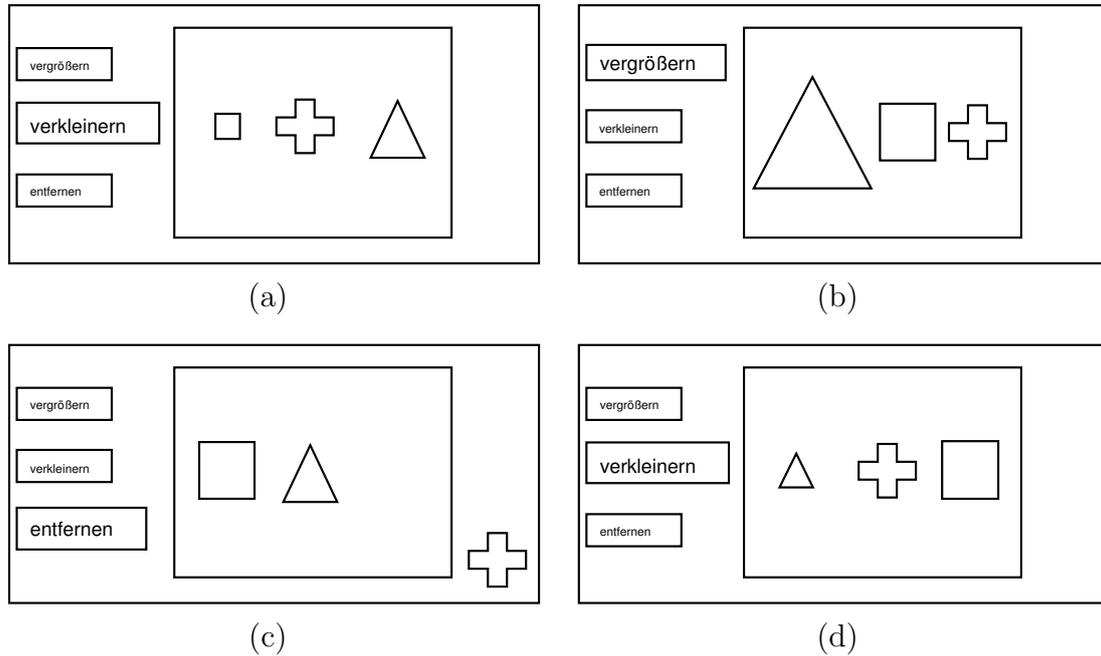


Figure 6: reference worlds for the fourth experiment, part 2

(46) (*What does Peter do? — Peter reduces the square.*)

1. Was macht Peter? — Peter VERKLEINERT das QUADRAT.
2. Was macht Peter? — Peter verkleinert das QUADRAT.

(47) (*What does Frank reduce? — Frank reduces the triangle.*)

1. Was verkleinert Frank? — Frank verkleinert das DREIECK.
2. Was verkleinert Frank? —
Frank VERKLEINERT das DREIECK.

In four dialogues the question is about an object (40, 43, 45, 47), in the other four dialogues the question is about an action (41, 42, 44, 46). The recordings of each dialogue differ only with respect to the stress pattern of the answer. In one recording only the noun of the object-DP is accentuated, and in the other recording the verb is accentuated as well. For each dialogue, we ask the TPs which is the ‘better’, more appropriate answer. As always, the experiment is a forced-choice experiment: The TPs have to decide for one recording, i.e. for one stress pattern.

We perform the experiment in two parts:

1. We perform the first part of the experiments with 22 TPs, among them 15 NSs and 7 NNSs. While playing the dialogue recordings we show the game board depicted in figure (5) as a reference world. We tell the TPs that the questioner knows the board – especially he knows which actions can be taken – but he does not know which action the respective player actually takes. The answerer shall inform the questioner appropriately.
2. We perform the second part of the experiment with 25 TPs, among them 18 NSs and 7 NNSs. While playing the dialogue recordings we show the game boards depicted in figure (6): The dialogues (40) and (46) are presented together with the game board (a), (41) and (43) together with (b), (42) and (45) together with (c) and (44) and (47) together with (d). Again, we tell the TPs, that the questioner knows the game boards, but he does not know which action the respective player takes. The answerer shall inform him appropriately.

The first and the second part of the experiment differ in the presentation of the game board(s): In the second part the pictures of the game boards already entail which action the player takes. In the first part this information is only given through the answers in the recorded dialogues. (We will see that the design difference does not lead to a significant difference in the results.)

Following a TOA, we predict that the TPs prefer the recording in which only the noun is accentuated if a question about an object is under discussion (*Was verkleinert/ vergrößert/ entfernt ...?*). In these dialogues, the recognition of the verb is not a necessary precondition for understanding the answer. We predict that the TPs prefer the accentuation of the verb and the noun if a question about an action is under discussion (*Was macht ...?*). In these dialogues, the recognition of the verb is a necessary precondition for the understanding of the answer. A TOA predicts a clear correlation between the question types and the TPs' accentuation preferences.

Following a focus theory *à la* Selkirk, we predict that the TPs always – regardless what kind of question is under discussion – prefer the recording in which only the noun is accentuated. Selkirk predicts that there is no correlation between the question types and the TPs accentuation preferences.

		accentuation			
		verb and noun		only noun	
<i>Was vergrößert/.../entfernt ...?</i>	total	39	(20.7%)	149	(79.3%)
	NSs	26	(19.7%)	106	(80.3%)
	NNSs	13	(23.2%)	43	(76.8%)
<i>Was macht ...?</i>	total	76	(40.4%)	112	(59.6%)
	NSs	49	(37.1%)	83	(62.9%)
	NNSs	27	(48.2%)	29	(51.8%)
<i>Was vergrößert ...?</i> (part 1)	total	20	(22.7%)	68	(77.3%)
	NSs	13	(21.7%)	47	(78.3%)
	NNSs	7	(25%)	21	(75%)
<i>Was macht ...?</i> (part 1)	total	38	(43.2%)	50	(56.8%)
	NSs	25	(41.7%)	35	(58.3%)
	NNSs	13	(46.4%)	15	(53.6%)
<i>Was vergrößert ...?</i> (part 2)	total	19	(19%)	81	(81%)
	NSs	13	(18.1%)	59	(81.9%)
	NNSs	6	(21.4%)	22	(78.6%)
<i>Was macht ...?</i> (part 2)	total	38	(38%)	62	(62%)
	NSs	24	(33.3%)	48	(66.7%)
	NNSs	14	(50%)	14	(50%)

Table 4: results of the fourth experiment

3.1.2 Results

The results of the experiment(s) are given in table (4): The results of both parts are pooled in the first table row; the results of the first part are given in the second row; and the results of the second part are given in the third row. The results of the first and the second part are not significantly different: The two-sided t-test for comparing the alternative hypothesis, that there is a correlation between the experimental setup (presentation of a single, neutral game board vs. presentation of different, more specific game boards) and the preferences when a question about an action is under discussion, with the null hypothesis that there is no such correlation yields

a p-value of 0.5905. The two-sided t-test for comparing the alternative hypothesis, that there is a correlation between the experimental setup and the preferences when a question about an object is under discussion, and the null hypothesis yields a p-value of 0.5516. Thus is, we can pool the data without affecting their significance.

On the one hand, the majority of the TPs always – irrespectively which kind of question is under discussion – prefer the recordings in which only the noun is accentuated. This supports Selkirk’s prediction and contradicts the TOA prediction. On the other hand, the data are highly significant regarding a correlation between the question types and the accentuation preferences. The one-sided t-test for comparing the null hypothesis (Selkirk: There is no correlation between question types and accentuation preferences) and the alternative hypothesis (TOA: The accentuation of the verb is preferred significantly more often when a question about an action is under discussion) yields a **p-value** of **2.524e-05**.¹⁰ This supports the TOA prediction and contradicts Selkirk’s prediction.

3.1.3 Discussion

The results of the experiment neither confirm focus theories *à la* Selkirk, nor do they confirm a TOA. If – as Selkirk assumes – the verb in the answers of the test dialogues is not be be accentuated at all, there should be no correlation between question context and accentuation preferences of the TPs. Yet, the results are highly significant in favour of such a correlation; Selkirk’s assumption therefore cannot be correct. However, the fact that in all contexts a majority of TPs prefer the recording with the sole accentuation of the noun (“Peter reduces the SQUARE”) to the recording in which both the verb and the noun are accentuated (“Peter REDUCES the SQUARE”), seems to support Selkirk’s assumption. That is, in the case of an answer to a question such as “What is Peter doing?”, a majority of the TPs prefer recordings with a non-optimal stress pattern.

In the recordings in which the verb (“reduces”) and the noun (“square”) were accentuated, both words are accentuated about equally strong. A possible explanation of the results may be that TPs consider the stress on the verb in the recordings that they heard too strong. It is possible that the predictions of optimal accentuation are correct, but that the stress on

¹⁰ This is the p-value for the pooled data (all TPs). The p-value for the NSs alone is 0.001275, and the p-value for the NSSs alone is 0.03157. The p-value for the data of the first part is 0.00308 (NSs alone: 0.01509; NNSs alone: 0.081234). The p-value for the second part is 0.002287 (NSs alone: 0.02793; NNSs alone: 0.02481).

the verb “reduces” must be weaker than the one on the noun “square”.

How do we arrive at this idea? — [Wagner, 2002] shows that in German sentences that are pronounced in citation form, words of different word classes are accentuated with different strength. Furthermore, content words at the end of intonational phrases are accentuated stronger than words before them.¹¹ (So far, we have treated ‘stress’ as a binary feature. For [Wagner, 2002], ‘stress’ is a gradual feature.) A sentence is pronounced in its citation form if it is uttered as a reply to the general question “what is the case”. When (the German translation of¹²) “Peter reduces the square” is pronounced in its citation form, then according to [Wagner, 2002] the nouns “Peter” and “square” are accentuated stronger than the verb “reduces”. “Square” is the last content word of a prosodic phrase and therefore receives the strongest stress; the stress on the article “the” is so weak that it can be ignored:

(48) PETER⁺⁺ REDUCES⁺ the SQUARE⁺⁺⁺.

According to optimal accentuation, in a sentence in citation form all the words must be accentuated whose non-recognition cannot be compensated for through standard operations of semantic enrichment. When the sentence “Peter reduces the square” is pronounced in citation form, the words “Peter”, “reduces” and “square” must optimally be accentuated. The article “the” does not need to be accentuated, because it can be compensated for through type-shifting the meaning representation of “square”. A TOA therefore predicts the accentuation of the same words as [Wagner, 2002]. However, because the theory as we outlined it so far treats ‘stress’ as a binary feature, it does not predict different stress *strengths*.

In example (39) the sentence “Peter reduces the square” answers the question what Peter is doing. This question is not the general question “what is the case”. The answer sentence “Peter reduces the square” is therefore not pronounced in citation form. Let us tentatively assume that a TOA correctly predicts which words are to be accentuated in sentences that are not pronounced in their citation form, and let us follow [Wagner, 2002] in determining stress strength. According to these assumptions, both the

¹¹ The latter point may contribute to the explanation of why the (incorrect) nuclear stress rule often appears quite plausible.

¹² For reasons of simplicity, our examples are in English. The hypotheses of [Wagner, 2002] are confirmed with German data. So, to be precise, our examples should be in German. However, we assume that the hypotheses apply to English as well.

verb “reduces” and the noun “square” must be accentuated; the verb, however, must be accentuated weaker than the noun:

(49) What is Peter doing? — Peter REDUCES⁺ the SQUARE⁺⁺⁺.

When the sentence “Peter reduces the square” is pronounced in its citation form, “reduces” must be accentuated weaker than “square”. There is no reason to assume that all words must be accentuated equally strong when “Peter reduces the square” is not pronounced in its citation form. It is therefore not merely possible but even likely that the sentence, when uttered as a reply to the question what Peter is doing, must be optimally accentuated as indicated in example (49). If this is indeed the case, we presented inappropriate stress patterns to the TPs in our experiment. We can explain the test results if we assume that majority of the TPs chose the recording without stress on “reduces” in order to make sure that “reduces” has a weaker stress than “square”. The TPs chose the recording with stress on the verb “reduces” more often when the question under discussion was what Peter is doing, because it is only in this answer that the verb has to carry an accent at all – albeit a weaker one than the noun “square”.

3.2 Production

We perform a production experiment in order to test our hypothesis on the different stress levels. In the experimental setup, we use the reference worlds in figure (7). Instead of asking the listeners concerning on the appropriateness of different accentuation patterns, we now want to find out whether differences in accentuation can be measured in the acoustic signal of speakers’ productions.

3.2.1 *Experiment*

The production experiment was split into a training phase and a test phase. During the training phase, the TPs were familiarised with the production task. Only the productions of the test phase were taken into account in the subsequent acoustic measurements and statistical analysis. The experiment consists of predefined questions asked by a person sitting opposite to the TP who was informed about the purpose of the experiment. Each question is matched with a reference world. The TPs now formulate an answer to each question based on the reference world in front of them. In a pretest, the TPs had been presented prerecorded versions of the questions headphones instead of presenting them in in a natural dialogue situation.

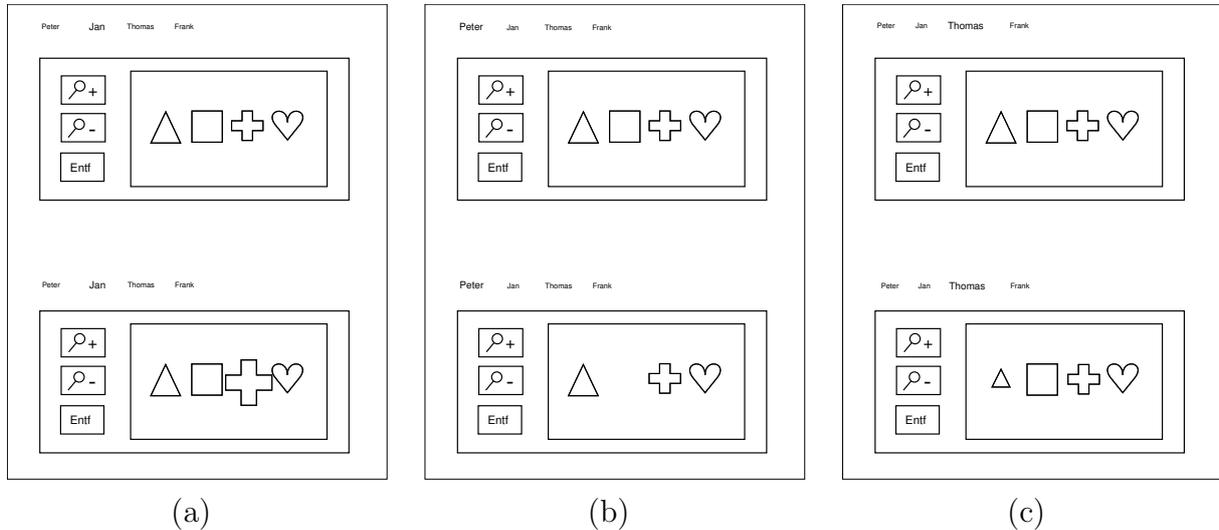


Figure 7: reference worlds for the training questions (50-52) of the production experiment

This procedure was chosen in order to minimise the risk of too much phonetic variation in the questions. However, it soon became clear that such an artificial setting lead to a somewhat unnatural behaviour of the TPs. Consequently, the more natural setting explained earlier was used. The experiment was finished by 26 participants. Most of them were undergraduate students of computational linguistics and/or phonetics. (The few others were graduate students of computational linguistics who were still naive concerning focus accentuation and *optimal accentuation*.) All speakers were recorded in an anechoic chamber using state of the art digital studio equipment.

The dialogues were designed carefully to be useful for a later phonetic analysis. i.e. each answer is uttered three times by each TP and each time, (s)he produces the answer to a different question: Either, the question asks for an action (condition 0), for an object noun (condition 1), or a subject (condition 2). In table (5) it is illustrated that TOA predicts an accent on the verb for the answer to the question in condition 0, but not in condition 1. However, TOA does not expect the strength of the accent of the verb to be as pronounced as in the object. Condition 2 can be regarded as a control condition. It ought to deliver us reference values for completely deaccented versions of both the verb and object. Our main focus of analysis lies on

condition	question	predicted answer
0	What does Peter do?	Peter REDUCES ⁺ the SQUARE ⁺⁺⁺
1	What does Peter reduce?	Peter reduces the SQUARE ⁺⁺⁺ .
2	Who reduces the square?	PETER ⁺⁺⁺ reduces the square.

Table 5: The different question conditions and the stress relations predicted for the TPs' answers by TOA.

the production of verbs in the various environments, but the objects in the answers are also analysed — mostly to document the validity of our measures. For our objects we expect an accentuation of similar strength both for condition 0 and 1, and a complete deaccentuation for condition 2.

In order to accomodate the TP to the task and to prevent too much hesitating or elliptical answers, a training phase (cf. examples (50-52).) preceded the experimental phase where answers were recorded and used in the subsequent analyses (test phase).

The following dialogues were produced in the order given below: Training phase (3 question-answer pairs); the reference worlds are given in figure (7):

- (50) (*Who enlarges the cross?*) (*Jan enlarges the cross.*)
 Wer vergrößert das Kreuz? (Jan vergrößert das Kreuz.)
- (51) (*What does Peter delete?*) (*Peter deletes the square.*)
 Was entfernt Peter? (Peter entfernt das Quadrat.)
- (52) (*What does Thomas do?*) (*Thomas reduces the triangle.*)
 Was macht Thomas? (Thomas verkleinert das Dreieck.)

Test phase (12 question-answer pairs); the reference worlds are given in appendix (A):

- (53) (*Who enlarges the triangle?*) (*Jan enlarges the triangle.*)
 Wer vergrößert das Dreieck? (Jan vergrößert das Dreieck.)

- (54) (*What does Peter reduce?*) (*Peter reduces the square.*)
Was verkleinert Peter? (Peter verkleinert das Quadrat.)
- (55) (*What does Thomas do?*) (*Thomas deletes the cross.*)
Was macht Thomas? (Thomas entfernt das Kreuz.)
- (56) (*Who reduces the heart?*) (*Frank reduces the heart.*)
Wer verkleinert das Herz? (Frank verkleinert das Herz.)
- (57) (*What does Jan do?*) (*Jan enlarges the triangle.*)
Was macht Jan? (Jan vergrößert das Dreieck.)
- (58) (*Who reduces the square?*) (*Peter reduces the square.*)
Wer verkleinert das Quadrat? (Peter verkleinert das Quadrat.)
- (59) (*Who deletes the cross?*) (*Thomas deletes the cross.*)
Wer entfernt das Kreuz? (Thomas entfernt das Kreuz.)
- (60) (*What does Peter do?*) (*Peter reduces the square.*)
Was macht Peter? (Peter verkleinert das Quadrat.)
- (61) (*What does Thomas delete?*) (*Thomas deletes the cross.*)
Was entfernt Thomas? (Thomas entfernt das Kreuz.)
- (62) (*What does Frank do?*) (*Frank reduces the heart.*)
Was macht Frank? (Frank verkleinert das Herz.)
- (63) (*What does Jan enlarge?*) (*Jan enlarges the triangle.*)
Was vergrößert Jan? (Jan vergrößert das Dreieck.)
- (64) (*What does Frank reduce?*) (*Frank reduces the heart.*)
Was verkleinert Frank? (Frank verkleinert das Herz.)

3.2.2 Results

The produced answers were subject to a detailed phonetic analysis. All phonetic measurements were carried out with the help of the software package Praat [Boersma and Weenink, 2007]. In order to test the various differences of accentuation, the boundaries of each lexically stressed syllable in the verbs and object nouns were hand labelled by a phonetic expert. Any disfluencies like hesitations and self-repairs were excluded from the analysis. Production „errors“ were taken into account in those cases where the speakers did not initiate a self-repair, e.g. they produced the word

enlarge instead of *reduce* but did not notice or repair their mistake. Alternative productions for the same referent (e.g. *quadrangle* instead of *square*) were taken into account as well. Our phonetic analyses were intended to measure the acoustic correlates of accentuation level, stress strength, or — in phonetic terminology — perceptual prominence. In a large number of phonetic studies (e.g. [Portele and Heuft, 1997, Claßen et al., 1998]), a set of possible acoustic correlates of prominence in German have been identified. Based on these studies, various candidates expressing prosodic prominence were measured in the speech signals of the productions:

- the **f0-range** in the lexically stressed syllable in the verbs and object nouns,
- the **duration** of each lexically stressed syllable in the verbs and object nouns,
- the **spectral slope** of the lexically stressed vowel in each verb and each object noun. As indicators of spectral slope, energy differences in various frequency bands and energy differences between H1 and H2 were measured.
- **psychoacoustic loudness** level in **some**, although this measure has been taken into account for completeness rather, as during the experiment, the TPs' distance to the microphone had not been controlled.

The results of the duration and f0-measurements are illustrated in table (6). The analysis of spectral slope and loudness did not show any significant effects and is not contained in the illustrations. It may be the case that our measure of spectral slope was inappropriate or we did not have enough material to get significant results. Our results ought not imply that spectral features are no valid correlate of accentuation in German, since its relevance for signalling perceptual prominence has been convincingly shown in a number of previous studies (e.g. [Claßen et al., 1998]).

3.3 Discussion

When regarding the productions of the noun, the acoustic analysis reveals an equal level of accentuation in objects for conditions 0 and 1 and a deaccented production in condition 2. The deaccentuation in condition 2 is revealed by less fundamental frequency movement expressed in a narrower f0-range, while the f0-range is almost identical between conditions 0 and 1. A t-test reveals that these impressions are statistically significant¹³.

question condition:		0	1	2
object realisations:	mean dur. (ms)	379	373	375
	f0-range	43.3	44.5	25.5***
verb realisations:	mean duration (ms)	274*	238	231
	mean f0-range (Hz)	28.0	26.3	26.0

Table 6: Means values of acoustic correlates of accentuation in the different contexts. Mean values that differ from both other conditions significantly are starred (*: $p < 0.05$, ***: $p < 0.001$).

Interestingly, the clear results for f0 are not replicated when we look at the durations. Mean durations of the stressed syllables in all conditions are almost identical (ranging between 2 and 6ms difference). Thus, while f0 movement clearly indicates the accentuation of the nouns, the duration does not. It is possible that this is due to the strong influence of final lengthening overriding the accentually conditioned increase of duration. However, it is known that the presence of a pitch accent is usually linked to a perception of prominence or accentuation, thus we regard the presence of a larger f0 range on the subject noun as an indicator of an accented production as predicted.

Looking at the acoustic prosodic features of the verb realisations in the different conditions, it is apparent that we find a different pattern. Both durations and f0-ranges are very similar for conditions 1 and 2, where we predicted a deaccentuation of the verb. However, condition 0 shows significantly longer durations than in conditions 1 (t-test, $p = 0.0112$) and 2 (t-test, $p = 0.0015$). For the f0-range we find a similar tendency, but the differences are subtle rather than statistically valid and cannot be used as an indicator of increased level of accentuation. However, the difference in duration between the predicted accented and unaccented contexts is roughly 40ms — taking into account that we did not find any durational difference between the unaccented and accented versions of the nouns, we take this as evidence that the verbs are indeed accented, but the speakers use a different strategy to signal it. With regards to recent psychoacoustic and

¹³Condition 0 vs. condition 1: $p = 0.93435$; Condition 0 vs. condition 2: $p = 9.2115e-05$, Condition 1 vs. condition 2: $p = 5.59322e-05$

psychophonetic findings, a difference of 40ms should be clearly audible ([Friberg and Sundberg, 1995, Quene, 2007]). Furthermore, recent phonetic models support the view that there exists a tradeoff between f0 movements and increase of duration in the signalling of perceptual prominence in German [Tamburini and Wagner, 2007]. Furthermore, there is evidence that f0 movements tend to indicate rather strong accents, while duration is used to signal weaker accents in German [Mixdorff and Widera, 2001]. Thus, the increase of duration can be interpreted as the presence of accentuation on the verb, albeit a relatively weak one.

3.4 Conclusions

Our results clearly support the prediction that verbs are accented in condition 0 only, while objects are accented in both conditions 0 and 1. Thus, we have convincing evidence that verbs are indeed accented when TOA predicts them to be, even if their accentuation is less strong than the one reached by the object nouns. We also find that the acoustic differences in duration are in a range where they are likely to be perceptually relevant. Thus, we interpret the findings that on the level of production, speakers tend to accentuate the verb in accordance with the TOA.

4 Conclusions

A focus that has to be accentuated can consist of multiple words. Which of these words must carry stress depends on the utterance context. An accentuation rule such as the *nuclear stress rule* (NSR), that does not refer to the utterance context, predicts partially inappropriate stress patterns.

[Selkirk, 1995] introduces the syntactic feature f , so that the words to be accentuated can be determined in relation to the utterance context: Contextually new words must carry the f -feature; they can receive this feature either through free assignment, or through projection. If a word receives the f -feature through free assignment, it must be accentuated; if it receives the feature through projection, it cannot be accentuated. The deciding reason for positing the f -feature lies in the explanation of the lack of accentuation on certain contextually new words. The feature would not be needed if all contextually new words were accentuated.

Within a theory of optimal accentuation (TOA), the lack of accentuation on contextually new words is accounted for by means of semantic enrichment rules: It must be possible to compensate for the non-recognition of unstressed words by referring to the discourse context, or through standard

operations of semantic enrichment. New words that are not recognised cannot be compensated for by referring to the context. If there is no need to recognise (and hence accentuate) such words, it must be possible to compensate for them through type-shifting.

Asymmetries in the accentuation of contextually new words that cannot be accounted for through semantic enrichment alone, must be interpreted as asymmetries in the *strength* of accentuation in a TOA. Regarding the experimental data described in this paper, such an interpretation is plausible.

A Reference worlds for the HAA production-experiment

Questions (53, 57, 63):

The first panel shows a control interface with a search bar and three buttons: a magnifying glass with a plus sign, a magnifying glass with a minus sign, and a button labeled 'Entf'. To the right is a display area containing four shapes: a triangle, a square, a plus sign, and a heart. The second panel is identical to the first.

Questions (54, 58, 60):

The first panel shows a control interface with a search bar and three buttons: a magnifying glass with a plus sign, a magnifying glass with a minus sign, and a button labeled 'Entf'. To the right is a display area containing four shapes: a triangle, a square, a plus sign, and a heart. The second panel is identical to the first.

Questions (55, 59, 61):

The first panel shows a control interface with a search bar and three buttons: a magnifying glass with a plus sign, a magnifying glass with a minus sign, and a button labeled 'Entf'. To the right is a display area containing three shapes: a triangle, a square, and a heart. The second panel is identical to the first.

Questions (56, 62, 64):

The first panel shows a control interface with a search bar and three buttons: a magnifying glass with a plus sign, a magnifying glass with a minus sign, and a button labeled 'Entf'. To the right is a display area containing four shapes: a triangle, a square, a plus sign, and a heart. The second panel is identical to the first.

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