The Duration Component of the Stress Effect in Stuttering

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Abstract
The purpose of the present study was to investigate whether there is a relationship between stuttering on stressed syllables and the duration of these syllables. Sixteen adults who stutter read a text consisting of 226 syllables. The relative stress of each syllable was rated, and syllables were categorized into long and short stressed syllables, unstressed syllables and intermediate syllables lying in-between. In order to isolate effects caused by within-word position from those caused by linguistic stress, syllables in initial and in subsequent positions were analyzed separately. In both word position categories stressed syllables were stuttered more often than unstressed syllables. Stuttering frequency of intermediate syllables seems to be in-between stressed and unstressed syllables, just as their stress level is rated in-between. Results regarding the duration of stressed syllables do not allow final conclusions.

The Duration Component of the Stress Effect in Stuttering

Introduction

The syllable is the unit which contains linguistic stress or accent. Syllabic stress seems to be characterized by an overall increase of articulatory effort (Fowler, 1995). In detail, stress is realized by increasing duration, loudness, fundamental frequency, and accuracy of articulation of syllables (Lehiste, 1970). Already in 1938 Brown reported a *stress effect* in stuttering. Stuttering events occurred more often on stressed than on unstressed syllables in polysyllabic words. In Brown's study more than 90 % of stuttering events occurred on initial sounds of words. This well-known feature of stuttering is called the *word initial effect*. In English as well as in German, the majority of syllables containing stress is in the first position of words. Therefore, word initial position and stress are confounded, requiring the isolation of the two effects. This can be done, for example, by analyzing stuttering frequency of first and subsequent syllables of words separately. Indeed, Brown found the stress effect in other than the first syllables of words as well.

Since Brown's early work several studies have dealt with stuttering and linguistic stress. Although different paradigms (e.g., the reading of word lists or connected speech) and definitions of stressed syllables (e.g., primary stress in polysyllabic words or peaks in a stress rating along a continuum) were used, it was consistently found that stuttering occurred more often on stressed than on unstressed syllables (Bergmann, 1986; Hahn, 1942; Klouda & Cooper, 1988; MacKay, 1970; Prins, Hubbard, & Krause, 1991; Wingate, 1984). In two studies using two-syllable words it was found that stuttering events are more strongly associated with word initial position than with stress (Hubbard, 1998; Weiner, 1984). This means that the first unstressed syllable of a polysyllabic word is more likely to be stuttered than a stressed syllable in later positions of the same word.

The authors cited above proposed several explanations of the stress effect, covering pure psychological, motor control and linguistic ones. However, there is a lack of detailed descriptions of processes which might lead to the occurrence of individual stuttering events during the production of stressed syllables. A concrete conception is necessary and may result from a more detailed investigation of the stress effect.

Such a more detailed investigation of the stress effect is the intention of this study and one starting-point might be the definition of stress. As stated above, stress is realized by variations in several parameters of speech production. On average, stressed syllables have a longer duration than unstressed syllables, but this is not true in every case. For instance, the italicized syllables in "*pit*fall" and "*peat*bog" are both stressed, but the stressed syllable in the first word is spoken with a shorter duration than in the second word, although the same vowel is used and therefore the example avoids an intrinsic duration effect. Stress can therefore be associated with a long or short duration of a syllable, and short stressed syllables may have a duration comparable to that of unstressed syllables. Considering the duration component of stress it becomes clear that the concept "stress", as used in the literature on stuttering, only incompletely describes the physical parameters characterizing an individual stressed syllable.

The duration component of stress could be important for the occurrence of stuttering, because long and short syllables seem to differ with respect to auditory control. Manipulation of auditory feedback, namely delayed or frequency-shifted auditory feedback, alters the production of long stressed syllables. Delayed auditory feedback prolongs vowel duration and frequency-shifted auditory feedback leads to compensatory responses in fundamental frequency (Donath, Natke, & Kalveram, 2002; Kalveram & Jäncke, 1989; Natke & Kalveram, 2001a). However, in short syllables the prolongation due to delayed auditory feedback is clearly smaller than in long stressed syllables. Responses to frequency-shifted auditory feedback have a latency of about 150 milliseconds, which is longer than many short syllables. It is concluded that in the production of long stressed syllables peripheral feedback plays a greater role than in the production of short syllables (Natke & Kalveram, 2001a). Several

authors suggested that persons who stutter rely on auditory feedback in an abnormal way (e.g., Lane & Tranel, 1971; Neilson & Neilson, 1987; Yates, 1963). Therefore, the question arises whether there is a relationship between the prominence of stuttering on stressed syllables and auditory control.

Theories which view stuttering from a motoric point argue that instability of motor production contributes to stuttering (cf. Van Lieshout, 1995). One can conclude that stuttering events should occur more often during articulatory movements, which require greater motoric demands. In line with Stevens' quantal theory (Stevens, 1998) it can be argued that in the production of short vowels a greater precision in articulation is required because long vowels are at the extremes of the vowel space, and the vocal tract area functions sufficient for their production are larger than for most short vowels. In addition, short stressed syllables are produced with a higher velocity of movement of articulatory gesture than long stressed syllables. Therefore, short stressed syllables may have higher requirements regarding precision and velocity than long stressed syllables.

As stated above, an important factor related with stuttering events is word initial position. Further are other language factors related with stuttering events, namely grammatical class (function-content distinction), sentence position, word length and phonetic type (initial phoneme) (Brown, 1945) as well as word frequency (Hejna, 1963). Wingate (1988) presents a detailed review of the language factors. There are numerous interrelationships among these factors as well as to stuttering. Wingate provides evidence that the relationships between syllable initial position as well as linguistic stress and stuttering events are stronger than any of the other factors, or all of them combined.

The present study is designed to investigate the stress effect in stuttering more detailed. It has been investigated whether there is a relationship between stuttering on stressed syllables and the duration of these syllables. Connected speech was investigated and the stress level of each syllable was rated as done before by Prins et al. (1991). However, in the study of Prins and colleagues the word initial effect was not considered. This is problematic, because within-word position and stress are confounded, as stated above. In the present study we addressed these two factors, which were specified by Wingate (1988) as the crucial dimensions describing the locus of stuttering events.

Method

Subjects

Fourteen males and 2 females who stutter and whose mother tongue is German participated in this study (*M*=33.4 years, *SD*=11.4 years). In order to avoid a floor effect, the precondition for participation was a stuttering frequency on first syllables of words above 5 % (see Data Analysis). None of the subjects showed a hearing deficit of more than 20 dB (audiometric test: Hortmann DA 323, Neckartenzlingen, Germany) or revealed any speech or language disorder other than stuttering. All subjects had participated in stuttering therapies in their past, but none in the two years before this study. The degree of stuttering severity was determined with Riley's Stuttering Severity Instrument (Riley, 1972). For 4 subjects the stuttering severity was judged as moderate, for 11 as severe, and for 1 subject as very severe (Riley-scale: *M*=25.9, *SD*=3.4).

Procedure

The subjects sat in a room facing a video camera with the experimenter being present. Subjects were instructed to read aloud a German standard text taken from a newspaper. No instructions regarding their stuttering were given. The text consisted of 283 syllables. The first sentence was not analyzed, leaving 226 syllables in 102 words for analysis.

Data Analysis

Stuttering events were defined as repetitions of a sound, a syllable or an one-syllable word, prolongations and blocks in accordance with Wingate's behavioral definition of stuttering (Wingate, 1964). Watching the video-recording repeatedly, stuttering events were identified and assigned to syllables using a data sheet on which each syllable of the text was printed in a separate line. Blocks were assigned to the following syllable. Some subjects used the repetition of an one-syllable word or a phrase for stalling a stuttering event or to get a "running start" (Van Riper, 1982). This was clearly observable, when the articulatory position of the initial sound of the word was already taken in or stuttering occurred in spite of the stalling behavior. In these cases not the repeated segment was rated as stuttered, but the following syllable.

Stuttering frequency can be reliably determined by trained raters, but a quite poor inter-rater agreement has been reported because the assignment of stuttering events to words or syllables remains difficult (Cordes & Ingham, 1994). Therefore, all speech samples in this study were reanalyzed by another rater. Rater one was the first author and rater two was the third author. Both raters had previously been involved in stuttering research for several years and had acquired comprehensive experience in analyzing dysfluent speech samples. Syllable-by-syllable agreement would be rather high because of the high number of syllables spoken fluently. Looking only at the syllables rated as being dysfluent, a stuttering event agreement of 82.8 % was found, which seems rather high in stuttering research (cf. Cordes & Ingham, 1994). Differences between both ratings were resolved by repeated listening to the sample and the final judgment of the first author.

Each syllable's stress was rated along a continuum applying a method that had previously been used by Prins and colleagues (1991): Because it is difficult to assign stress patterns to syllables which are stuttered, a choral procedure described by Boomsliter, Creel and Hastings (1973) was used. Three normal-speaking adults read the text in unison. It is assumed that under these circumstances each speaker uses the stress pattern that he expects other individuals to use. That way speakers employ the typical prosody of their language. The reading was recorded and played repeatedly, so that the relative stress of each spoken syllable could be rated on a scale from 1 to 9. Three stress categories were defined independent of word boundaries: "Stressed syllables" are surrounded on each side by syllables with a lower stress value, while "unstressed syllables" are surrounded by syllables with higher stress values. Syllables with stress values in-between are called "intermediate syllables". In order to

test reliability of this assignment, two raters made stress ratings of the reading. A syllable-by-syllable agreement of 80.5 % related to the three stress categories was found. For further data analysis the mean rating of both raters and the resulting assignment of syllables to stress categories were used.

In order to investigate a possible relationship between the duration of stressed syllables and the occurrence of stuttering events, stressed syllables were divided into "short" and "long". For this the vowel duration of stressed syllables was determined. Narrow band spectrograms were made using Sound Forge (Version 4.0, Sonic Foundry, Madison, USA; FFT size: 256 samples corresponding to about 6 milliseconds, FFT overlap: 75 %) for each stressed syllable read by one of the three persons reading the text in unison. Durational measurements of vowels were taken from the display. Onset and end of the vowels were marked where energy of the second formant crosses approximately 25% of maximum energy indicated by a color scale. To assess reliability of this measurement vowel duration of 30% of the syllables was measured again by a second rater. The mean difference between the two raters was 16 milliseconds. Vowel duration of stressed syllables varied between 27 and 241 milliseconds with a mean value of 100.8 milliseconds. Syllables with a vowel duration above the mean value were categorized as long stressed syllables, and syllables with a vowel duration below the mean value were categorized as short stressed syllables. Additionally, a rating of stressed syllables in these two categories was performed. A quite high agreement of 86.1 % between the rating in short stressed and long stressed syllables and the categorization based on durational measurement was found suggesting that the rating might substitute the durational measurements in future studies.

First and subsequent syllables of words were analyzed separately. The words in the text contained 102 first syllables and 124 subsequent syllables. For syllables in first position, there were 51 stressed syllables (33 short and 18 long), 33 intermediate, and 18 unstressed syllables. Therefore, first syllables were almost three times more frequently stressed than unstressed. For subsequent syllables there were 35 stressed syllables (17 short and 18 long), 32 intermediate, and 57 unstressed syllables. Therefore, 50.0 % of the first syllables and 28.2 % of the subsequent syllables bore stress, whereas 17.6 % of the first syllables and 46.0 % of the subsequent syllables were unstressed.

Stuttering frequencies were calculated separately for the different stress categories as well as for first and subsequent syllables. In order to avoid a floor effect not only in first syllables by the precondition of a stuttering frequency above 5 % but also in subsequent syllables, only the data of subjects whose stuttering frequency was above 5 % were used in the analysis of subsequent syllables. For comparisons between the stuttering frequencies one-tailed paired *t*-tests were calculated. For first syllables and subsequent syllables each, stuttering frequencies between all four stress categories (short stressed, long stressed, intermediate, unstressed) were compared (resulting in 2×6 tests). Additionally short and long stressed syllables were combined to stressed syllables and compared with intermediate and unstressed syllables (additional 4 tests). Therefore, 16 simultaneous tests were performed and the significance level $\alpha=5$ % was corrected to $\alpha'=\alpha/16=0.003125$ according to Bonferroni. Stuttering frequencies of first and subsequent syllables were not compared directly, because single- and poly-syllabic words differ with respect to word frequency and word class, which might confound the results.

Results

Overall, subjects stuttered on 623 syllables corresponding to a mean stuttering frequency of 17.2 %. 479 stuttering events occurred on first syllables of words (corresponding to a stuttering frequency of 29.4 % on first syllables), whereas 144 stuttering events occurred on subsequent syllables (corresponding to a mean stuttering frequency of 7.3 % on subsequent syllables). This shows a clear word initial effect. To isolate the stress effect from this word initial effect, stuttering frequencies in each stress category were calculated for first and subsequent syllables of words separately.

Table 1 summarizes the results for first syllables of words. For each stress category, stuttering frequencies were calculated based on the total number *N* of syllables in the respective category. For example 33.3 % in the category "Unstressed" of subject 1 means that the subject stuttered 6 of 18 syllables in first position of words of the reading text rated as unstressed. Individual stuttering frequency on first syllables varies from 6.9 % up to 69.6 %. In the first position of words stressed syllables (both, short and long) were stuttered significantly more often than intermediate ($t(15)=3.217$, $p=.003$) and than unstressed syllables ($t(15)=3.373$, $p=.002$).

Table 1: Stuttering frequencies of *first syllables* of words for each stress category. Stuttering frequencies were calculated based on the total number *N* of syllables in the respective category.

Subject	Total (*N*=102)		Stressed [%] (*N*=51)		Intermediate [%] (*N*=33)	Unstressed [%] (*N*=18)
	Number	Percentage	Short [%] (*N*=33)	Long [%] (*N*=18)		
1	36	35.3	39.2		30.3	33.3
			36.4	44.4		
2	11	10.8	11.8		3.0	22.2
			18.2	0.0		
3	69	67.7	80.4		57.6	50.0
			78.8	83.3		
4	24	23.5	37.3		9.1	11.1
			30.3	50.0		
5	22	21.6	27.5		15.2	16.7
			24.2	33.3		
6	15	14.7	17.7		18.2	0.0
			21.2	11.1		
7	21	20.6	29.4		15.2	5.6
			24.2	38.9		
8	24	23.5	15.7		33.3	27.8
			12.1	22.2		
9	18	17.6	21.6		18.2	5.6
			30.3	5.6		
10	58	56.9	58.8		48.5	66.7
			60.6	55.6		
11	18	17.7	25.5		12.1	5.6
			36.4	5.6		
12	32	31.4	43.1		24.2	11.1
			42.4	44.4		
13	8	7.8	7.8		12.1	0.0
			9.1	5.6		
14	71	69.6	70.6		69.7	66.7
			72.7	66.7		
15	45	44.1	52.9		36.4	33.3
			57.6	44.4		
16	7	6.9	9.8		3.0	5.6
			9.1	11.1		
M	29.9	29.4	34.3 (22.0)		25.4	22.6
(SD)	(20.6)	(20.2)	35.2 (21.9)	32.6 (24.9)	(19.5)	(22.2)

Figure 1 shows the stuttering frequency for first syllables dependent on stress category as well as the corresponding *p*-values. Long stressed syllables were not stuttered significantly more often than intermediate and unstressed syllables, although corresponding *p*-values were low. However, short stressed syllables were stuttered significantly more often than intermediate and unstressed syllables. Stuttering frequencies for short and long stressed syllables and for intermediate and unstressed syllables did not differ.

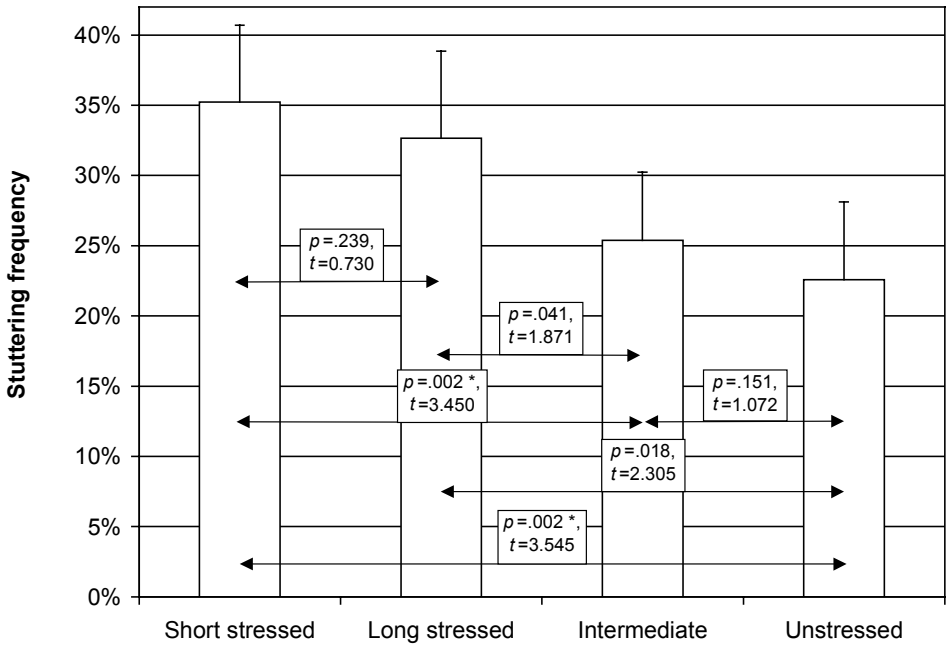

Figure 1: Mean stuttering frequencies for *first* syllables of words and standard error, dependent on stress category. Significance is indicated by an asterisk at a Bonferroni corrected significance level $\alpha'=\alpha/16=0.003125$ (df=15).

In Table 2 the results for subsequent syllables of words are summarized. Only subjects were included whose stuttering frequency on subsequent syllables was above 5 %. Because of the word initial effect only eight subjects remained after that. Individual stuttering frequency on subsequent syllables varies from 5.7 % up to 18.6 %. Stressed syllables (both, short and long) were stuttered significantly more often than unstressed syllables (t(7)=5.272, p=.001). Stuttering frequencies of stressed syllables and intermediate syllables do not differ significantly (t(7)=2.968, p=.011).

Table 2: Stuttering frequencies of *subsequent syllables* of words for each stress category. Stuttering frequencies were calculated based on the total number *N* of syllables in the respective category. Only subjects were included whose stuttering frequency on subsequent syllables was above 5 %.

Subject	Total (*N*=124)		Stressed [%] (*N*=35)		Intermediate [%] (*N*=32)	Unstressed [%] (*N*=57)
	Number	Percentage	Short [%] (*N*=17)	Long [%] (*N*=18)		
3	23	18.6	28.6		31.3	5.3
			41.2	16.7		
4	11	8.9	28.6		3.1	0.0
			29.4	27.8		
5	14	11.3	17.1		9.4	8.8
			17.7	16.7		
7	9	7.3	22.9		3.1	0.0
			23.5	22.2		
10	13	10.5	11.4		15.6	7.0
			11.8	11.1		
12	20	16.1	40.0		15.6	1.8
			47.1	33.3		
14	17	13.7	31.4		9.4	5.3
			41.2	22.2		
15	7	5.7	14.3		6.3	0.0
			17.7	11.1		
M	18.0	11.5	24.3 (9.7)		11.7	3.5
(SD)	(6.5)	(4.4)	28.7 (13.1)	20.1 (7.8)	(9.3)	(3.5)

Figure 2 shows the stuttering frequency for subsequent syllables dependent on stress category and the corresponding *p*-values. Short stressed syllables were stuttered significantly more often than unstressed syllables and there is a strong tendency that they were also stuttered more often than intermediate syllables ($t(7)=3.795$, $p=.004$). Long stressed syllables were stuttered significantly more often than unstressed syllables. The other comparisons do not reach the corrected significance level.

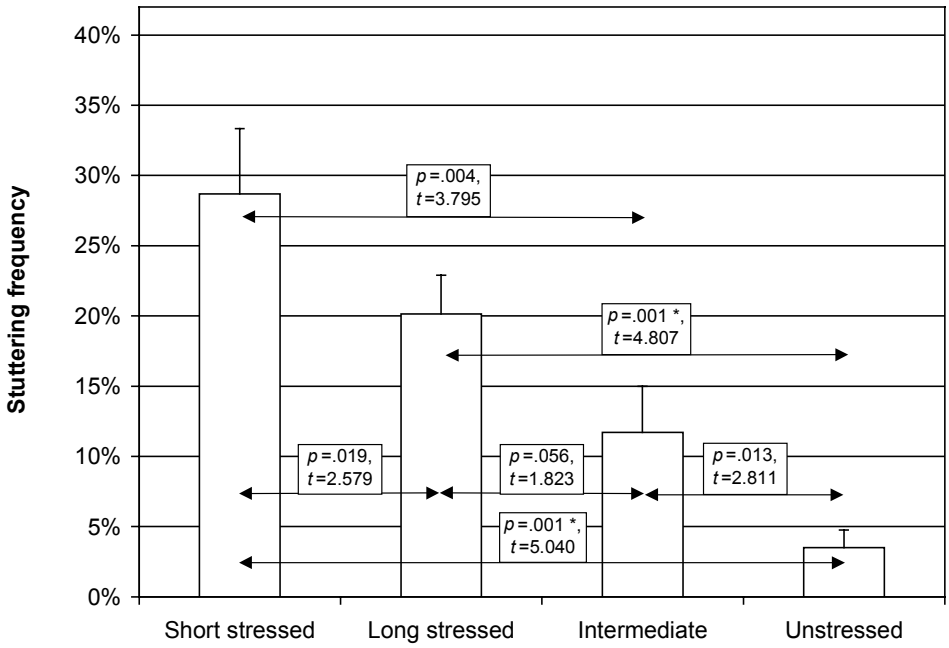

Figure 2: Mean stuttering frequencies for *subsequent* syllables of words and standard error, dependent on stress category. Significance is indicated by an asterisk at a Bonferroni corrected significance level $\alpha'=\alpha/16=0.003125$ (df=7).

Discussion

In this study it was confirmed that stuttering events occur more often on stressed than on unstressed syllables. Because syllables in initial position of words contain linguistic stress more often than syllables in subsequent positions, syllables in both positions were analyzed separately. This way the two effects – increased stuttering on word initial position and increased stuttering on stressed syllables – are isolated from each other. In word initial position as well as in subsequent positions stressed syllables were stuttered more often than unstressed syllables (first position: factor 1.5; subsequent positions: factor 7). The stuttering frequency of intermediate syllables seems to be in-between stressed and unstressed syllables, just as their stress level is rated in-between.

Stuttering in adults is characterized by accessory behaviors and e.g. increased stuttering on certain sounds is common (Van Riper, 1982). Such features may overlay the stress effect for example, when a person frequently stutters on a certain sound but this sound is the initial sound of an unstressed syllable, which is not likely to be stuttered in general. Children who had been stuttering for only a short time show fewer accessory behaviors and, therefore, the stress effect might be investigated more directly. Evidence for the presence of a stress effect in children who stutter comes from a preliminary study with six pre-school children (Natke, Sandrieser, Pietrowsky, & Kalveram, 2001). With stress analysis based on a model of adult prosody, stuttering events occur more often in short stressed syllables than in unstressed syllables. The children were 3;0 to 4;6 years old and had been stuttering on an average for less than one year. The two children who had been stuttering for only three months showed the effect as well. These results make it appear likely that the stress effect is not a consequence of stuttering (maybe in some way due to coping or compensation). It rather seems to be present at the very onset of the disorder.

Results of the present study with adults regarding the categorization of stressed syllables into “short” and “long” do not allow final conclusions. In subsequent syllables of words stuttering frequency of short stressed syllables was higher than of long stressed syllables (factor 1.4), but the comparison did not reach the corrected significance level. The same was found in pre-school children, where only syllables in word-initial position were analyzed. Therefore an influence of the duration component of linguistic stress on stuttering cannot be ruled out and further research needs to be carried out.

Compared to the present study greater speech samples and monologues instead of reading should be used. Stuttering frequencies on reading and monologue may differ to a high degree. Central processing for these tasks differ at least because of involvement of visual cortex and orthographic encoding in reading. It cannot be ruled out that these processes may bias the auditory system, too. Monologue can be seen as the more natural speaking task and should therefore be investigated in future studies to increase ecological validity.

Future research might show whether there are developmental patterns regarding the stress effect. An important factor seems to be grammatical class. In English as well as in German function words are usually unstressed, whereas content words carry stress. Adults are more likely to stutter on content words than on function words (Brown, 1945). With increasing age, content word stuttering increased and function word stuttering decreased (Au-Yeung, Howell, & Pilgrim, 1998; Bloodstein & Gantwerk, 1967; Bloodstein & Grossman, 1981; Rommel, 2001). Therefore, the relationship between stuttering events and stress might be weaker in children, as pointed out by Howell, Au-Yeung and Sackin (1999). Nevertheless, our preliminary study cited above indicates that the stress effect can already be found in pre-school children. Future studies with children who stutter should control for grammatical class to gain more insight into the relationships between linguistic stress, stuttering events and grammatical class in this age group.

In the study of Prins et al. (1991), in the present study, and in our study with pre-school children (Natke et al., 2001) the typical prosody of the language was taken as a basis of analysis instead of the actual stress pattern produced by the subjects. This method was chosen

because it is difficult or even impossible to rate linguistic stress of a syllable which is stuttered (one might think of a prolongation combined with an increase of loudness). In such a case the *intended* stress pattern is desired, which obviously cannot be observed. The typical prosody of the language was taken as an approximation for the actual stress pattern. Both might correspond to a high degree, but in an individual case the stress rating might differ. A solution of that problem might be to let the person speak a stuttered utterance again. Because of the adaptation effect it is more likely that the repetition of an utterance is performed fluently. A second fluent production can then be seen as an individual approximation of the originally intended stress pattern of the stuttered syllable. Another possibility is to utilize fluency enhancing conditions, which do not modify speech production in an essential way. For example, frequency-shifted auditory feedback reduces stuttering (Howell, El-Yaniv, & Powell, 1987) but does not alter vowel duration (Natke & Kalveram, 2001b), fundamental frequency (Natke, Grosser, & Kalveram, 2001) or intensity (Howell, 1990) to a greater extent, three parameters characterizing linguistic stress. This method might be applicable at least in schoolchildren and adults.

As stated above, there is a need for future studies to examine the duration component in the stress effect on stuttering. The aim of studies investigating factors related to stuttering should be to present empirically testable conceptualizations of the underlying mechanisms that result in the core behaviors of this disorder. In this way the need of a conceptual framework for the individual instance of stuttering will be fulfilled (Bloodstein, 1995; Conture, 2001).

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