
Effects of Category and Rhyme Decisions on Sentence Production

Hans-Georg Bosshardt
Waltraud Ballmer
Ruhr-Universität Bochum
Bochum, Germany

Luc F. de Nil
University of Toronto
and
Toronto Western Research Institute
Toronto, Canada

The aim of the present experiment was to investigate differences between persons who stutter and persons who do not stutter during the production of sentences in a single task versus two dual-task conditions. Participants were required to form a sentence containing 2 unrelated nouns. In dual-task conditions, rhyme and category decisions were used as secondary tasks. The results for 14 adults who stutter and 16 adults who do not stutter are reported. Dependent variables were the number of correct rhyme and category decisions, decision latencies, length, number of propositions, sentence latency, speech rate of sentences, disfluencies, and stuttering rates. The results indicated that both groups reduced the average number of correct rhyme and category decisions when this task was performed concurrently with sentence generation and production. Similarly, the 2 groups of participants did not differ with respect to the correctness and latency of their decisions. Under single-task conditions the sentences of both groups had a comparable number of propositions. But under dual- as compared with single-task conditions persons who stutter significantly reduced the number of propositions whereas persons who do not stutter did not show a significant dual- versus single-task contrast. Experimental conditions did not significantly influence stuttering rates. These results suggest that persons who stutter require more processing capacity for sentence generation and articulation than persons who do not stutter and that both groups keep stuttering rates at a constant level by adjusting the number of propositional units of their linguistic productions. The results support the view that the organization of the speech-production system of persons who stutter makes it more vulnerable to interference from concurrent attention-demanding semantic tasks.

KEY WORDS: sentence production, stuttering, adults, dual task

Etiological factors of stuttering can be roughly categorized into problems with motor control of speech movements on the one hand (for overviews, see Kent, 2000; Peters, Hulstijn, & van Lieshout, 2000) and into difficulties in linguistic planning and coding on the other hand (Bernstein Ratner, 1997; Karniol, 1995; Perkins, Kent, & Curlee, 1991; Postma & Kolk, 1993, 1997). In recent years it has become increasingly clear that "... *planning* for speech-language production is as much if not more so related to stuttering than *execution*..." (Conture, 2000, p. 9). There are empirical and theoretical reasons to assume that the probability of stuttering is positively related to the processing demands involved in speech planning. Such a relationship between processing demands and stuttering has been found for children (Bernstein Ratner & Sih, 1987; Kadi-Hanifi & Howell, 1992; Logan & Conture, 1995; Melnick & Conture, 2000; Rommel, 2001; Yaruss, 1999) and adults (Bosshardt, 1995; Jayaram, 1984; but see also Silverman & Bernstein Ratner, 1997). Similarly, it has been found that the probability of stuttering is also

related to word length and other phonological and phonetic indicators of articulatory difficulty (Howell, Au-Yeung, & Sackin, 2000; Wingate, 1988). However, the evidence provided by these studies is weakened by difficulties in determining the processing demands of particular utterances or linguistic units independently of stuttering probability. Dual-task experiments, by contrast, allow the experimenter to induce additional processing loads and to observe their effects on stuttering and other parameters of speech.

In the present experiment a dual-task methodology was used to test the assumption that stuttering results from an overload of the speech-planning system. Unfortunately, however, in earlier dual-task studies only nonverbal tasks were used as secondary tasks (pursuit tracking: Arends, Povel, & Kolk, 1988, and Thompson, 1985; finger tapping: Bruttin & Trotter, 1985, 1986, and Sussman, 1982; gross-motor task: Kamhi & McOsker, 1982). When speaking under these secondary-task conditions speech fluency remained largely unchanged. Only Arends et al. (1988) found less disfluency when talking while performing a tracking task than when speaking under single-task conditions. These results, however, are limited by the fact that these nonverbal tasks overload limited-capacity attentive control but probably not the language-specific components of the cognitive processing system that are used for speech production (see Bosshardt, 1999). In the present sentence-production experiment, therefore, verbal secondary tasks were used in order to overload those subsystems that are specifically relevant for sentence generation and production.

Expectations about the effects of secondary tasks on sentence content and speech fluency can be derived from speech-production theories. In modern theories of speech production it is generally assumed that oral speech is generated at multiple levels (e.g., conceptual planning; semantic, syntactic, and phonological encoding and articulation, see Bock, 1995; Bock & Levelt, 1994; Bosshardt, in press; Garrett, 1990; Herrmann & Grabowski, 1994; Levelt, 1989) and that processing at some of these levels must be performed relatively automatically to eliminate or minimize attentional demands and interference from concurrent processes in other parts of the system (Bock, 1982; Herrmann & Grabowski, 1994). In theories of speech production (and perception) the duality of automatic and attention-demanding subprocesses is generally accepted and seems to have a neurophysiological basis (e.g., Goldman-Eisler, 1968; Jorm, 1986; Rochon, Walters, & Caplan, 2000).

Dual-task experiments with nonstuttering speakers (Jou & Harris, 1992; Power, 1985; Rummer, 1996) suggest that the generation of ideas and semantic content are attention-demanding activities whereas syntactic, phonological, and articulatory processes do not seem

to be affected by secondary tasks. Given these results, Gathercole and Baddeley (1993) concluded that the central executive system as a limited-capacity system is involved in semantic and lexical planning because it coordinates the information flow between different processing levels.

There exist several indications that a competition between speech-related subprocesses may also be involved in the development of stuttering. It was found that in comparison with nonstuttering children, stuttering children show deficits in tests of lexical, syntactical, phonological, and phonetic abilities (Anderson & Conture, 2000; Bernstein Ratner, & Sih, 1987; Howell et al., 1999, 2000; Kadi-Hanifi & Howell, 1992; Melnick & Conture, 2000; Ryan, 1992; Wingate, 1988). Lack of automaticity is only one possible explanation of trade-off relationships in the efficiency of different domains of functioning. Another interpretation is based on the assumption that the integration of linguistic information demands more attentive control when one of the subprocesses involved in speech planning is below the efficiency level of other components.

There are some indications that in adults the efficiency of phonological (Postma & Kolk, 1993, 1997; Wingate, 1988) and of semantic coding (Bosshardt, 1993; Bosshardt & Fransen, 1996; Wingate, 1988) is lower in persons who stutter than in persons who do not stutter. For the present context it is important to note that processing difficulties at any level increase attentional processing demands at the central executive level. This increase can occur either because the deficient subprocess can be performed only under attentive control or because the integration of linguistic information needs more attention-demanding replanning and corrections.

In a previous experiment (Bosshardt, 1999) it was observed that when continuous word repetition was performed concurrently with a mental calculation task, both stuttering and nonstuttering persons, as groups, significantly increased the number of disfluently repeated words. A subgroup of stuttering persons, however, who under single-task conditions were comparable to the other participants, showed an extreme increase in the number of disfluencies under dual-task conditions. Because word repetitions can be considered to be highly automatic, this task presumably is rather resistant to interference from higher level cognitive processes, which may explain the variable performance among the stuttering group. It was expected, therefore, that more pronounced interference effects could be demonstrated in a less automatized sentence-production task. With this understanding a sentence-production task was used as primary task and cognitive continuous decisions as secondary tasks, which required the subjects to encode semantic (category task) or phonological (rhyme task)

information, to store and retrieve this information, and to make response decisions.

One set of expectations about the possible effects of these two secondary tasks on sentence-production performance can be based on the assumptions that both tasks impose processing loads on the central limited-capacity system (Baddeley, 1996; Gathercole & Baddeley, 1993) and that this system is the only source of interference between the tasks. With this perspective it can be expected that under dual- as opposed to single-task conditions the sentences will be semantically less elaborate regardless of the nature of the secondary task (cf. Power, 1985). Because rhyme and category decisions presumably interfere with sentence planning it can also be expected that the latency of sentence production will be longer under dual- than under single-task conditions. Alternatively, it is possible that final segments of sentences are planned while their first segments are being articulated (Ferreira, 1991, 1993; Lindsley, 1975). If so, one would predict that sentence latency will not be affected by the single- or dual-task differences. Finally, it is also possible that overt sentence production (phonological coding and articulation) interferes with planning of later sentence segments. Under this assumption it was predicted that dual- as compared with single-task conditions will result in sentences that are produced more disfluently.

Another set of expectations can be developed under the assumption that rhyme and category decisions each impose different demands on the processing system. The decision latencies for the category decision task may be longer than those for the rhyme decision task because nouns can be categorized semantically in multiple ways. Therefore, it is possible that several categories have to be retrieved before a decision about the category relationship between two nouns can be made. In contrast, rhyming decisions may take comparatively less time because phonological information is encoded only once. Given these assumptions it can be expected that the category decision task will have more pronounced effects on the semantic sentence content and the latency of sentence production than the rhyme task. Generalizing from Goldman-Eisler's (1968) findings that pauses are positively related to the amount of semantic and conceptual planning it also could be expected that sentences would be produced with more pauses and a lower speech rate under category than under rhyme decisions.

A third set of expectations about differences between the two secondary tasks can be derived from the fact that they are based on the storage and processing of qualitatively different codes. Storage and processing of a phonological code used in rhyme decisions may interfere with the oral production of the sentence more than semantic processing used in category decisions. On the

basis of Postma and Kolk's (1993) theory, it can be expected that concurrent phonological encoding, which is required for the rhyme decisions and sentence production but not for the category decisions, would interfere with fluent sentence production by increasing stuttering. Because category decisions are based on semantic processing it could be predicted that category decisions will create interference within the semantic system, thereby increasing the more "typical" disfluencies (Yaruss, 1998) and hesitations related to sentence planning and correction phenomena (e.g., pauses, revisions).

A fourth and final set of expectations is related to performance differences between persons who stutter and persons who do not stutter. There are some indications that the efficiency of phonological (Perkins et al., 1991; Postma & Kolk, 1993, 1997) and of semantic coding (Bosshardt, 1993; Bosshardt & Fransen, 1996; Wingate, 1988) is lower in persons who stutter than in persons who do not stutter. This led to one of the aims of the present study, which was to investigate whether rhyme and category decisions as secondary tasks differentially affect sentences produced by persons who do and do not stutter. The predictions that can be derived from this assumption depend on whether both groups produced sentences that impose comparable processing load on the speech-production system. Under this presupposition it was expected that concurrent phonological encoding (in rhyming decisions) would increase the stuttering rate of persons who stutter more than that of nonstutterers. Similarly, it was assumed that concurrent semantic coding (in category decisions) would interfere with the sentence-planning activities of persons who stutter more than with those of persons who do not stutter. Therefore it was expected that under category decisions persons who stutter would produce their sentences with a higher disfluency rate than persons who do not stutter.

Method

Subjects

Nineteen adults who stutter and 22 who do not stutter participated in the investigation. All participants were native speakers of German. The participants were recruited via newspaper advertising, flyers, posters on the university campus, and from self-help groups. The two groups of participants were matched for age, education, sex, and scores on a written version of a subtest in the Hamburg-Wechsler intelligence test (HAWIE-R; Tewes, 1991) for adults (repeating numbers forward and backwards) and on a vocabulary test (Schmidt & Metzler, 1992). After matching, 10 men and 4 women who stutter and 13 men and 3 women who do not stutter (see Table 1) remained in the stuttering and nonstuttering groups,

Table 1. Personal characteristics of participants: mean age, performance in memory and vocabulary tests and words stuttered (%) in oral reading of a 200-word text.

Person variables	M	(SD)	Min	Max
Persons who do not stutter (N = 16)				
Age	33.70	(8.33)	18	55
Digits forwards	8.40	(1.93)	4	11
Digits backwards	7.40	(2.06)	4	10
Vocabulary test	33.90	(2.25)	28	38
Persons who stutter (N = 14)				
Age	35.90	(10.09)	24	55
Digits forwards	8.30	(1.54)	5	11
Digits backwards	7.60	(1.09)	6	9
Vocabulary test	32.90	(2.25)	29	37
Words stuttered	8.40	(13.83)	0	48

respectively. Analyses of variance did not show significant group differences in memory (digits forwards performance: $F[1, 24] = 0.03, p < 0.85$; digits backwards performance: $F[1, 24] = 0.11, p < 0.75$) and vocabulary (WST) tests [$F(1, 24) = 1.28, p < 0.27$]. There was no indication that any of the persons who did not stutter had a history of disturbances of speech, and none had ever received speech therapy. None of the persons who stutter had received treatment in the year before participating in the experiment. Percentage of words stuttered was determined based on oral reading of a 200-word newspaper article. The three persons with higher than average stuttering rates (8.4%) stuttered on 48% (96 words), 27% (53 words), and 9% (18 words) of the 200 words. Stuttering was defined as prolongation and repetition of sounds, syllables, and single-syllable words and auditorily identifiable indications of tension. Further, the two groups of participants were matched for educational level so that 5 of the stuttering and 5 of the nonstuttering persons had between 8 and 10 years of schooling (Hauptschule or Sekundarstufe 1 [intermediate secondary school or basic high school]), whereas 9 of the stuttering and 11 of the nonstuttering persons had 13 years of schooling (university entrance qualification) or a university education. The two groups of participants were comparable with respect to education level [$\chi^2(2) = 0.09, ns$].

Apparatus

A Sony TCD-D3 DAT-recorder with a Sony ECM-S220 microphone was used to record the stuttering screening. During the experiment the speech productions were recorded using a Shure SM microphone on one channel of a Computerized Speech Lab (CSL 4300 B, Kay Elemetrics). The stimuli were presented on the plasma-screen of a laptop Toshiba T 3100 SX computer.

Speech times and durations were measured with Computerized Speech Lab and Computerized Speech Research Environment (CSRE, AVAAZ Innovations, Inc.).

Materials

For the sentence-generation task, three lists of four noun pairs (Sg-lists) were constructed (see Appendix A). Each noun pair was used in one sentence-production trial. One Sg-list was used for single task, one for rhyme, and one for category. To balance differences between lists over speaking conditions, each list was used for different conditions in different subgroups of participants. To further minimize potential list effects, the noun pairs of different lists were made categorically comparable. Every noun referred to one of the following categories: animal, room, object, material. Within each list the nouns were pairwise combined so that *animal-room*, *object-material*, *room-object*, *material-animal* pairs occurred at corresponding list positions. Every participant received one of the lists for sentence production as a single task, another for sentence production under category task, and the third for sentence production under rhyme decisions.

For the rhyming task four lists of 11 nouns were constructed (Rh-lists). Within each Rh-list half of the nouns rhymed with the preceding noun, and half of them did not. Similarly, four lists of 11 nouns were constructed for the category decision task (Ca-lists). Within each Ca-list half of the nouns belonged to the same semantic category as the preceding noun, and half of them did not. For each task, an additional Sg-, Rh-, and Ca-list was used for training. Within each Rh- and Ca-list, the order of correct yes-no decisions was random.

All words used in any of the lists were nouns commonly used in everyday language. They were first selected according to the criteria mentioned above and then their frequencies were checked in the COSMAS I (2001) newspaper corpus of 52,967,000 word forms. A frequency index for each stimulus word was determined by calculating the logarithm of the frequency ratio between the most frequent word in the German language (*der* [the]) and every stimulus word. The average frequency indices of the nouns in the Sg-, Rh-, and Ca-lists were comparable (Sg: $M = 3.555$, range = 2.388 to 5.050; Rh: $M = 3.745$, range = 1.951 to 5.152; Ca: $M = 3.698$, range = 2.531 to 5.647). Because all average frequency indices and frequency ranges were comparable no further frequency-based selection criteria were applied.

Procedure

Every participant was asked to fill out a questionnaire with basic personal background information.

Subsequently, the memory and vocabulary tests were administered and the stuttering rate was determined.¹ During the experiment, the participants sat in front of a computer screen on which the stimulus words were presented. The three speaking conditions (i.e., sentence generation as single-task, sentence generation with rhyme, and sentence generation with category decisions) were performed by all participants in a repeated-measurement design. Each participant generated 4 sentences under single-task and 4 under dual-task conditions (i.e., concurrently with rhyme and with category decisions) respectively. In each of the three speaking conditions the experiment consisted of four trials, preceded by three training trials. To compensate for possible practice effects the order of the three tasks was counterbalanced in a latin square.

In each speaking condition, stimuli were presented at fixed time intervals independently of subjects' responses. In single-task trials, the noun pair for sentence generation was presented 2500 ms after the start of the trial for a duration of 2500 ms. The two words of the noun pair were presented side by side on the lower half of the screen. The participants were instructed to generate a sentence as fast as possible upon presentation of the noun pair and with the two nouns in the same order as presented and not to change the words nor use them as composites. Ten seconds after the beginning of a trial (or 7.5 s after the beginning of the presentation of the noun pair) the end of a trial was signaled by an acoustic stop signal. Participants were allowed to finish their sentence after the stop signal. The experimenter started the next trial when the participant was ready to continue.

Every secondary-task (rhyming or category) trial started with the presentation of the first secondary-task word for either the rhyme (Rh-list) or the category-decision (Ca-list) task, respectively. The secondary-task stimuli were presented in the middle of the upper half of the screen for a duration of 2500 ms each. After 2500 ms, the first stimulus word was erased and the second word appeared at the same place on the screen. After the presentation of the second, and each following secondary-task word, the participants indicated their decisions whether or not the last word presented rhymed or belonged to the same semantic category as the previous word stimulus. They did so by pressing the Yes-button with the right hand or the No-button with the left hand. Examples of the three training trials were used to make sure that the subjects understood the meaning of a rhyming or semantic relationship between the words. In order to make the responses to the Yes/No decisions motorically and cognitively as easy as possible they were

assigned to different hands. Because under both secondary-task conditions half of the decisions required Yes and half required No reactions, potential differences between the two reactions or hands cannot account for the differences between conditions. Within each secondary-task trial 11 nouns were successively presented.

In dual-task trials, simultaneously with the fourth word of the rhyme or category list (i.e., 7500 ms after the beginning of the trial), a noun pair for sentence generation was presented in the lower half of the screen. Participants were instructed to perform the sentence-generation task concurrently with the rhyme- or category-decision task, to create and utter the sentence as quickly as possible and at the same time perform the secondary task. Instructions for sentence generation under dual-task conditions were otherwise identical to those for single-task conditions. Thus, within a dual-task trial the first three rhyme and category decisions were performed without concurrent activities. Only when the two words for sentence production were presented, together with the fourth word of the secondary task, did participants make decisions while concurrently planning and producing the sentence. Thirty seconds after the beginning of the trial under dual-task conditions the end of the trial was acoustically signaled.

Data Analysis

All oral productions during the experiment were transcribed. The transcripts were used to determine the number of syllables spoken and the number of propositions (see Appendix B) in the sentences. Disfluency and stuttering events were scored by the second author by listening several times to the speech channel with CSL and CSRE.

Statistical Analyses

The variables of the sentence production and the decision tasks significantly deviated from a normal distribution and had heterogeneous variances. The Kruskal-Wallis analysis of variance by ranks with alignment for means was chosen as a nonparametric test of the main effects and interactions (Bortz, Lienert, & Boehnke, 1990; see also Marascuilo & McSweeney, 1977). Because all measurements were at least on interval level, data were aligned for means. The variables of the sentence-generation task were analyzed in a two-factorial design with group (nonstuttering and stuttering participants) and speaking condition (sentence generation as single task, under rhyme and category decisions). The main effect of speaking condition was tested for significance after data alignment for the group effect and for the interaction between group and speaking condition.

¹ The experiment was performed after EGG- and lower-lip EMG-electrodes were set into place. These electrodes were needed for another experiment which was run in the same session.

Similarly, the interaction between group and speaking condition was tested after alignment for group and speaking-condition effects.

The dependent variables of the secondary task were analyzed in a three-factorial design with group, speaking condition, and block as the three factors. For the block factor the scores of two adjacent rhyme or category decisions were averaged. This yields a total of five blocks. The first block of decisions was performed before the noun pairs for the sentence-generation task were presented. The following decisions were made while the noun pair for the sentence-generation task was presented and the participants began to generate and produce the sentences. For the majority of trials participants had completed the sentence before the third block of decisions.

The criterion of statistical significance for main effects and interactions was set at $\alpha = .05$. For significant group-with-speaking-condition interactions, the simple effects of speaking condition were tested with a nonparametric Friedman test (Bortz et al., 1990) for each group separately. The Bonferroni-corrected criterion of significance for these tests was set at $\alpha^* = \alpha/2 = .025$. When the main effect or any of the simple effects for speaking condition was significant, two orthogonal comparisons were made with a nonparametric Wilcoxon signed-rank test. In accordance with the theoretical expectations described in the introduction, the single-task performance was compared with the average of the two dual-task performances, and the performances under rhyme and category conditions were compared. The Bonferroni-corrected criterion of significance for these two statistical comparisons was set at $\alpha^* = \alpha/2 = .025$.

Nonparametric measures D of the effect size of the orthogonal contrasts were calculated (Kraemer & Andrews, 1982; see also Hedges & Olkin, 1984). D can be seen as a nonparametric equivalent of Cohen's parametric effect size statistic d . Differences between the effect sizes calculated for each group were used to describe the size of the between-group difference in this contrast (Kraemer & Andrews, 1982, p. 409).

Selection of Data

Trials with valid sentences were selected for the statistical analysis, and scores were averaged for every participant and speaking condition. A sentence was scored as correct if it was a complete sentence with at least one finite verb, contained both nouns in the prescribed order, and was completed before the end of the trial. Sentences not referring to the real world for which some imaginative context could be found, and which were otherwise correct, were included (e.g., "Wool comes from the caterpillar").

Dependent Variables for Rhyme and Category Decisions

Number of Correct Rhyme and Category Decisions

In both decision tasks, only correct button presses that were recorded during the presentation of a given stimulus were counted. For every participant the number of correct responses per block in the rhyming and the category decision was averaged over trials.

Latencies of Rhyme and Category Decisions

The time interval between the presentation of a stimulus word and the subjects' pressing of the Yes/No button was measured in milliseconds for each stimulus word and averaged over blocks and the four trials of a task. Only latencies of correct responses were analyzed, which limits them to the stimulus interval of 2500 ms and kept all values within 2.58 SD (corresponding to 99% of the normal distribution).

Dependent Variables for Sentence Production

Number of Correct Sentences

The total number of correct sentences was determined for each participant and each task and summed over the trials of a task. (See details in selection of data section.)

Sentence Latency

The time interval between the beginning of the trial and the onset of the first syllable of the first word of the intended sentence was measured in milliseconds and averaged over the trials of a task. When the first word of the sentence was produced disfluently or stuttered these events were not included in the latency interval. Comments or filled pauses, however, were included in the latency period. That is, the first linguistic sound belonging to the sentence was counted as the beginning of the sentence.

Number of Syllables

The length of a sentence was defined as the number of its syllables. The syllables of the intended sentence were counted, excluding stuttered syllables and disfluencies (see definitions below).

Number of Propositions

The number of propositions expressed in a sentence was determined and averaged over the valid sentences

of each condition. The coding rules proposed by Johnston and Kamhi (1984) were made applicable to sentences of adult speakers (see Appendix B for further details).

Disfluencies

All occurrences of silent pauses, fillers, filler words, revisions, repetitions of phrases, syllable lengthening without indication of tension, and comments within the sentence were counted as disfluency. For every valid sentence for each participant the number of disfluencies was determined and averaged over the trials of a task. The percentage of disfluencies was determined on the basis of the average number of disfluencies and the average number of syllables per sentence.

Syllables Stuttered

All repetitions and substitutions of sounds, syllables, and words,² together with lengthening of vowels and consonants, and all audible indications of tension (intensity and duration) were counted as stuttering. For every participant and sentence the total number of syllables stuttered was determined. The percentage of syllables stuttered was determined on the basis of the average number of syllables stuttered and the average number of syllables per sentence.

Speech Rate

Speech rate was defined as the number of syllables produced per second. For this measure all disfluently produced syllables were included. For every valid sentence, speech rate was averaged over the trials of a task for each participant.

Reliability

All ratings were determined by the second author. Interrater agreement between the independent ratings of the second and first author were determined for the dependent variables number of correct sentences, disfluencies, and syllables stuttered. Interrater reliabilities were based on ratings for 120 sentences, half of which were produced by persons who stutter and the other half by persons who do not stutter (corresponding to 33% of total number of sentences). Interrater agreement for number of correct sentences was 92% ($N = 120$), the corresponding within-rater agreement was 96% ($N = 359$). For disfluencies, interrater agreement was 77% ($N = 120$), within-rater agreement was 79% ($N = 359$). For syllables stuttered interrater agreement was 90% ($N = 120$), within-rater agreement was 87% ($N = 359$). To improve the actual objectivity of the disfluency and

²In order to treat one- and multi-syllable words comparably repeated or substituted words were scored as stuttering.

stuttering ratings all problematic scorings were consensually decided upon in discussions between the first and second author.

To determine the reliability of the number of propositions, a student was trained with sentences from a different experiment to correctly apply the rating criteria. After the training the student independently scored the number of propositions for all sentences of the present study. Interrater agreement for the number of propositions was 90% ($N = 318$). Intrarater reliability was determined for 120 sentences (half from persons who stutter and half from persons who do not stutter) and was 98.3% ($N = 120$).³

Results

Category and Rhyme Decisions

Number of Correct Decisions

The average numbers of correct category and rhyme decisions were comparable in both groups ($H = 3.52$, $df = 1$, ns), and none of the interactions with group were significant (Group \times Block \times Speaking Condition: $H = 15.46$, $df = 4$, ns ; Group \times Speaking Condition: $H = 0.95$, $df = 1$, ns ; Group \times Block: $H = 4.61$, $df = 4$, ns). The number of correct category and rhyme decisions was significantly influenced by Speaking Condition ($H = 6.62$, $df = 1$, $p < .01$) and by the interaction of this factor with Block ($H = 20.35$, $df = 4$, $p < .02$). In Blocks 3 and 5 the number of correct category decisions was significantly higher than that of rhyme decisions ($z = 0.38$, ns , $D = 0.25$; $z = 1.01$, ns , $D = 0.25$; $z = 2.63$, $p > .01$, $D = 1.28$; $z = 0.10$, ns , $D = 0.53$; $z = 2.10$, $p < .04$, $D = 0.96$; also see Table 2). The block effect was also significant ($H = 89.52$, $df = 4$, $p < .000$).

Latency of Decisions

In this analysis of variance the data from one stuttering participant were excluded because in Blocks 2, 3, and 4 this participant did not show any correct decisions and consequently no latency data were available. Four other participants had one missing value each in Block 2, which was replaced by an estimated value calculated using multiple regression (Frane, 1976). Neither the main effect for Group ($H = 2.37$, $df = 1$, ns) nor the interactions with this factor were significant (Group \times Speaking Condition: $H = 0.02$, $df = 1$, ns ; Group \times Block: $H = 8.66$, $df = 4$, ns ; Group \times Speaking Condition \times Block: $H = 4.16$, $df = 4$, ns).

³After correcting for chance agreement (Scott, 1955), interrater reliability was 77% above chance level for number of correct sentences, 44% for disfluencies, 73% for syllables stuttered, and 87% for number of propositions. For intrarater reliability, the corresponding percentages above chance level were 85%, 52%, 68%, and 97.8% respectively.

Table 2. Average number of correct rhyme and category decisions per block (standard deviations in parentheses).

Block	Persons who do not stutter (N = 16)	Persons who stutter (N = 14)	Entire sample (N = 30)
Category decisions			
1	6.01 (1.22)	6.75 (1.60)	6.33 (1.45)
2	3.57 (1.93)	3.17 (1.60)	3.40 (1.67)
3	5.51 (2.41)	5.83 (1.85)	5.60 (2.11)
4	5.75 (1.64)	5.52 (1.88)	5.63 (1.65)
5	6.15 (1.76)	6.63 (1.66)	6.33 (1.67)
Rhyme decisions			
1	6.54 (1.77)	5.83 (1.55)	6.17 (1.80)
2	3.31 (2.33)	2.88 (1.39)	3.03 (1.99)
3	5.00 (1.62)	4.33 (1.74)	4.70 (1.77)
4	5.76 (2.05)	5.50 (1.52)	5.63 (1.65)
5	5.73 (2.20)	5.72 (1.41)	5.70 (1.80)

Latencies were significantly influenced by Speaking Condition ($H = 23.66$, $df = 1$, $p < .000$), by block ($H = 88.29$, $df = 4$, $p < .000$), and by the interaction Block \times Speaking Condition ($H = 59.31$, $df = 4$, $p < .000$). Latencies of category decisions were significantly longer than those of rhyme decisions in Blocks 1 and 4 but not in the other blocks ($z = 4.66$, $p < .000$, $D = 1.09$; $z = 1.85$, ns , $D = 0.22$; $z = 0.21$, ns , $D = 0.04$; $z = 3.62$, $p < .000$, $D = 1.09$; $z = 1.35$, ns , $D = 0.60$; also see Table 3). The largest latencies were found in Block 2, and the smallest in Blocks 1 and 5. Response latencies increased in Block 2 about 400 ms and decreased gradually in the following blocks.

Sentence Production

Number of Correct Sentences

Group ($H = 0.42$, $df = 1$, ns) and the interaction Group \times Speaking Condition ($H = 3.62$, $df = 2$, ns) did not, but Speaking Condition ($H = 6.84$, $df = 2$, $\alpha < .03$) did significantly influence the number of correct sentences (see Table 4). Both groups produced significantly fewer correct sentences under dual than under single task ($z = 2.60$, $p < .01$, $D = -0.73$).

Sentence Latency

Sentence latencies were not significantly different in the two groups ($H = 0.25$, $df = 1$, ns) (see Table 4). Speaking Condition significantly influenced sentence latencies ($H = 6.28$, $df = 2$, $p < .04$). Both groups had significantly longer sentence latencies under dual- than under single- task condition ($z = -2.59$, $p < .01$, $D = 0.26$) and under category than under rhyme condition ($z = -2.32$, $p < .02$, $D = 0.08$). The interaction between Group and Speaking Condition did not significantly influence sentence production latencies.

Table 3. Average latencies (in seconds) of rhyme and category decisions per block (standard deviations in parentheses).

Block	Persons who do not stutter (N = 16)	Persons who stutter (N = 13)	Entire sample (N = 29)
Category decisions			
1	0.982 (0.132)	1.032 (0.166)	1.023 (0.169)
2	1.369 (0.426)	1.392 (0.362)	1.383 (0.395)
3	1.104 (0.222)	1.165 (0.175)	1.119 (0.213)
4	1.137 (0.177)	1.169 (0.210)	1.149 (0.190)
5	0.923 (0.117)	0.999 (0.185)	0.956 (0.150)
Rhyme decisions			
1	0.803 (0.102)	0.860 (0.123)	0.830 (0.122)
2	1.227 (0.181)	1.216 (0.231)	1.232 (0.229)
3	1.080 (0.134)	1.166 (0.209)	1.129 (0.189)
4	0.927 (0.174)	1.023 (0.157)	0.975 (0.180)
5	0.847 (0.100)	0.978 (0.156)	0.909 (0.144)

Number of Syllables

The two groups of participants did not produce sentences that significantly differed in syllable numbers ($H = 0.42$, $df = 1$, ns), but number of syllables was systematically influenced by Speaking Condition ($H = 8.00$, $df = 2$, $p < .02$). The interaction between Group and Speaking Condition was not significant ($H = 5.00$, $df = 2$, ns). Orthogonal contrasts between single and dual tasks and between Rhyme and Category condition were not significant ($z = 1.30$, ns , $D = -0.17$; $z = 1.66$, ns , $D = -0.62$). Because the overall effect of Speaking Condition was significant, but none of its orthogonal comparisons were, the present data do not allow a clear conclusion about the effects of Speaking Condition on sentence length in terms of number of syllables.

Number of Propositions

The factor Group had no significant effect ($H = 0.42$, $df = 1$, ns) but Speaking Condition ($H = 25.03$, $df = 2$, $p < .000$) and the interaction Group \times Speaking Condition ($H = 7.73$, $df = 2$, $p < .02$) did. Under single-task conditions the sentences of both groups had a comparable number of propositions. But under dual-task conditions persons who stutter produced sentences with a smaller number of propositions than persons who do not stutter (see Table 4). Simple main effects of Speaking Condition within each group were significant (persons who do not stutter: $\chi^2[2] = 8.04$, $p < .025$; persons who stutter: $\chi^2[2] = 11.48$, $p < .01$). For persons who stutter the contrast between single- and dual-task was significant ($z = 2.58$, $p < .01$, $D = -1.07$), whereas the contrast between rhyme and category fell just short of the Bonferroni-corrected criterion of significance ($z = 1.98$, $p < .048$, $D = -0.56$). For persons who do not stutter the

Table 4. Means and standard deviations of sentence-related variables.

Speaking condition	Persons who do not stutter (<i>N</i> = 16)		Persons who stutter (<i>N</i> = 14)	
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
Number of correct sentences				
Sentence	3.75	(0.58)	3.64	(0.63)
Sentence + Rhyme	3.50	(0.89)	3.29	(0.63)
Sentence + Category	3.44	(0.89)	3.64	(0.82)
Sentence latencies (ms)				
Sentence	10780.00	(1236.02)	10639.00	(976.92)
Sentence + Rhyme	11159.00	(2132.81)	10651.00	(915.25)
Sentence + Category	11836.00	(2793.43)	11490.00	(3093.67)
Number of syllables				
Sentence	9.67	(1.59)	9.73	(2.17)
Sentence + Rhyme	9.37	(1.60)	8.08	(0.53)
Sentence + Category	9.84	(2.20)	8.53	(1.03)
Number of propositions				
Sentence	1.56	(0.43)	1.73	(0.81)
Sentence + Rhyme	1.30	(0.41)	1.10	(0.14)
Sentence + Category	1.66	(0.66)	1.29	(0.24)
Disfluencies				
Sentence	3.31	(4.22)	4.28	(4.77)
Sentence + Rhyme	3.16	(3.58)	3.56	(3.60)
Sentence + Category	1.47	(1.75)	7.50	(6.36)
Syllables stuttered				
Sentence	0.00	0.00	6.98	(8.80)
Sentence + Rhyme	1.22	(1.83)	6.50	(7.51)
Sentence + Category	1.10	(3.17)	8.21	(6.45)
Speech rate				
Sentence	5.03	(0.94)	3.55	(0.93)
Sentence + Rhyme	5.12	(1.19)	3.65	(1.16)
Sentence + Category	5.41	(0.95)	3.37	(0.97)

contrast between dual- and single-task conditions was not significant ($z = 0.81$, *ns*, $D = -0.32$), but the contrast between Category and Rhyme conditions was ($z = 2.35$, $p < .02$, $D = -0.67$). Because the experimental conditions were balanced only over groups, the present experiment was primarily designed to investigate differences between conditions and their interaction with Group. On this basis it seems even more remarkable that only 1 of the 14 stuttering participants produced sentences for which the average number of propositions was higher under dual- than under single-task conditions, whereas 6 of the 16 nonstuttering participants showed performance differences in this direction. Only 7 of the 14 stuttering participants produced a higher number of propositions under Category than under Rhyme condition,

whereas 11 of the 16 nonstuttering participants showed performance differences in this direction.

Disfluencies

The percentage of disfluencies was not significantly influenced by Group ($H = 3.82$, $df = 1$, *ns*) and Speaking Condition ($H = 1.26$, $df = 2$, *ns*), but it was influenced by the interaction Group \times Speaking Condition ($H = 12.69$, $df = 2$, $p < .025$). Simple main effects of Speaking Condition within each group failed the Bonferroni-corrected criterion of significance in both groups (persons who do not stutter: $\chi^2[2] = 1.37$, *ns*; persons who stutter: $\chi^2[2] = 6.50$, $p < .04$). Effect size estimates for single-dual (persons who do not stutter: $D = -0.32$; persons who stutter:

$D = 0.79$) and Rhyme-Category contrasts (persons who do not stutter: $D = 0.49$; persons who stutter: $D = -0.57$) had opposite signs in each group, and the net effect size differences between groups were large (single-dual: $D = 1.11$; Rhyme-Category: $D = 1.06$). Thus, descriptively persons who stutter increase their disfluency rates under Category relative to Rhyme conditions (2 persons showed negative and 10 positive differences), whereas persons who do not stutter show the opposite pattern of differences (8 persons showed negative and 5 positive differences). The statistical reliability, however, of these differences remains questionable (also see Table 4).

Syllables Stuttered

The percentage of syllables stuttered in the sentence was significantly higher for persons who stutter than for the group of nonstuttering persons (about 7% vs. 1%) ($H = 12.75$, $df = 1$, $p < .001$). Speaking Condition ($H = 4.18$, $df = 2$, ns) and the interaction between Speaking Condition and Group ($H = 5.49$, $df = 2$, ns) did not significantly influence the percentages of syllables stuttered.

Speech Rate

Speech rate in persons who do not stutter was found to be significantly higher than that of persons who stutter ($H = 12.75$, $df = 1$, $p < .001$). Speaking Condition ($H = 5.11$, $df = 2$, ns) and the interaction Group x Speaking Condition were not significant ($H = 0.48$, $df = 2$, ns).

Discussion

In dual-task experiments, performance differences in one task are interpreted in terms of performance differences in the second task. We, thus, begin with discussing the results of the secondary task. Both subject groups significantly decreased the number of correct category and rhyme decisions when performing them concurrently with a sentence-generation task (i.e., in Block 2). Similarly, for both groups the latency of correct decisions was increased during Blocks 2 and 3.

The findings observed during the secondary-task performance suggest that rhyme and category decisions are both attention-demanding processes that, together with sentence generation and production, draw on a central executive system of limited capacity as conceptualized by Baddeley (1996, 1997). An alternative interpretation may be that the observed interference between both tasks is perceptually mediated because the words for both the decision and the sentence-generation tasks were presented visually. This interpretation, however, seems unlikely because all words were presented for 2.5 s, and the longest average decision latency was less than 1.4 s (cf. Table 3). This leaves an average presen-

tation time of more than 1 s to read the noun-pair for the sentence-generation task. Rayner and Pollatsek (1989) estimated that the identification time for words is about 200 ms. It thus seems highly likely that the participants of the present experiment had enough time to identify the noun-pairs for sentence generation in addition to the word for the decision task, supporting the interpretation that the performance decrements under dual-task condition indicate that the two tasks draw on overlapping processing resources.

The most important result of the present study was that the number of propositions was significantly influenced by the interaction of the group factor with the speaking condition. The two groups of participants were carefully matched with respect to their personal characteristics, and they were also comparable with respect to their secondary-task performance in Block 1 (i.e., before they started to create and utter sentences). Therefore, the group differences observed in the number of propositions can be interpreted as indicating differences in the use of processing resources under dual- as compared with single-task conditions, rather than as general differences in overall processing capacity. The effect size of the single-dual contrast was smaller for nonstuttering than for stuttering persons (-0.32 vs. -1.07). The net effect size of the between-group difference was $D_{\text{net}} = 0.75$, which indicates that the size of this contrast was more pronounced in the group of stuttering than of nonstuttering speakers. The effect sizes of the rhyme-category contrasts were comparable in both groups (-0.67 vs. -0.56). Thus, the significant effect of the group-by-speaking-condition interaction on the number of propositions was largely due to the fact that the single- versus the dual-task contrast was more pronounced in the stuttering than in the nonstuttering persons. These results indicate that for stuttering as compared with nonstuttering persons sentence generation and production are to a greater extent under the control of the central executive system. In this view stuttering persons reduce the number of propositions under dual-task conditions and thereby also reduce the overload of the executive system.

However, in addition to the central executive system other more language-specific subsystems should be taken into consideration. The number of propositions in the sentences of the nonstuttering persons was significantly influenced by rhyme and category decisions. Although category decision latencies were even longer than rhyme latencies (see Table 3), both groups showed a similar tendency to generate sentences with more propositions when generating sentences concurrently with category- than with rhyme-decision tasks. Although for stuttering persons the difference between the rhyme and category tasks was statistically not

significant ($p = .048$), the effect size was only slightly smaller than that of the nonstuttering persons (-0.67 vs. -0.56). We were not able to identify a statistical procedure for calculating the statistical power of these nonparametric tests. However, because our sample sizes were smaller than 20 and because the effect sizes of the rhyme-category contrast were comparable in the two groups, it seems safe to state that there is a relatively high risk of erroneously accepting the null hypothesis for the stuttering group. On the basis of the present results a final decision whether the rhyme and category tasks differentially influence the number of propositions in the sentences of persons who stutter must be left open. In any case the present results underline the fact that processes in language-specific subsystems must be taken into account and that secondary task effects can be explained only incompletely with reference to processes in the central executive system.

An alternative way of interpreting these results is based on the modularity concept as proposed by Fodor (1983). In this view, the difference between the two groups can be thought of as resulting from a speech generation or production system that differs in its degree of "modularization." Persons who stutter could be thought of as having a speech-production system that is organized in a less modular way, thereby making the system more vulnerable to interferences from concurrent activities.

Contrary to our original expectations, stuttering rates were not significantly affected by the speaking conditions (dual vs. single and rhyme vs. category) and their interactions with group. On average, persons who stutter showed a higher stuttering rate in sentences with more than one proposition than in one-proposition sentences (0.95 vs. 0.53). Persons who do not stutter did not show comparable differences in stuttering rate as a function of the number of propositions (0.05 vs. 0.07). These observations indicate that persons who stutter can reduce their stuttering rates by reducing the amount of semantic planning and creating sentences consisting of only one proposition. One interpretation of these results is that the stuttering rate of persons who stutter only increases as a result of concurrent cognitive processes when the communicative situation does not allow a reduction in the amount of speech-related planning. On the basis of the present results alone this interpretation may appear somewhat speculative, but it can account for the observation that concurrent attention-demanding processes increase stuttering rate in a word-repetition paradigm (Bosshardt, 1999) but not in the present sentence-production paradigm, where processing load can be reduced by reducing the amount of linguistic planning so that a low stuttering rate can be maintained.

Normal disfluencies were significantly influenced by the interaction between group and speaking condition. This interaction is largely due to the fact that persons who do not stutter have a lower disfluency rate under the category than the rhyme condition, whereas persons who stutter have a comparably higher disfluency rate (see Table 4). Although the difference between the disfluency rates in rhyme and category conditions was not significant within each group, the effect sizes of the two groups differed in opposite directions. However, no significant simple effects of Speaking Condition were found within the two groups. Given the relatively low reliability of this measure and the inconsistent statistical inferences no theoretical interpretation for these results can be offered.

Conclusion

The present results suggest that sentence planning and production impose a comparatively higher processing load on persons who stutter than on persons who do not stutter. This seems to be largely due to the fact that in stuttering speakers both phonological and semantic subprocesses involved in sentence planning and production draw on a limited-capacity central processing system. Persons who do not stutter were observed to perform semantic processing in a manner that depends less on central processing capacity.

The results of the present experiment do not support the assumption that persons who stutter have specific difficulties in phonological coding (see Postma & Kolk, 1993, 1997). It was found that the sentences that the two groups produced concurrently with rhyme decisions were comparable. Because these results were obtained with adults it cannot be excluded that difficulties in phonological encoding may play a role in earlier stages of language development. The present results, however, are compatible with the general framework developed by Perkins et al. (1991). According to them, processing difficulties arising from any part of the speech-production system can induce stuttering and disfluencies. The present results, however, are more specific. They show that stuttering and nonstuttering adults differ in lexical-semantic processing demands and suggest that the amount of semantic planning can be related to stuttering rate.

The present results are based on an experimental procedure in which the secondary task was equally present during sentence planning and articulation. It seems to be important to also investigate interference effects that may specifically affect either planning or articulation. Based on the present data it can only be assumed that the two groups differ in either one or both phases of speech production.

Acknowledgments

This work was partially supported by grants from the Deutsche Forschungsgemeinschaft (DFG, BO-827/5-1) awarded to the first author and from the Natural Sciences and Engineering Research Council of Canada awarded to the third author. We are also grateful to Dipl.Psych. Andreas Henning for his help in the preparation of the experiment, to Katharina Nebel and Astrid Thiel for their help in collecting the data, and to Heike Nowert for help in determining reliability.

References

- Anderson, J. D., & Conture, E. G.** (2000). Language abilities of children who stutter: A preliminary study. *Journal of Fluency Disorders, 25*, 283–304.
- Arends, N., Povel, D.-J., & Kolk, H.** (1988). Stuttering as attentional phenomenon. *Journal of Fluency Disorders, 13*, 141–151.
- Baddeley, A.** (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 49A*, 5–28.
- Baddeley, A.** (1997). *Human memory: Theory and practice* (3rd ed.). Hove, U.K.: Psychology Press.
- Bernstein Ratner, N.** (1997). Stuttering: A psycholinguistic perspective. In R. F. Curlee & G. M. Siegel (Eds.), *Nature and treatment of stuttering* (pp. 99–127). Needham Heights, MA: Allyn & Bacon.
- Bernstein Ratner, N., & Sih, C.** (1987). Effects of gradual increases in sentence length and complexity on children's disfluency. *Journal of Speech and Hearing Research, 52*, 278–287.
- Bock, J. K.** (1982). Towards a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review, 89*, 1–47.
- Bock, J. K.** (1995). Sentence production: From mind to mouth. In J. L. Miller & P. D. Eimas (Eds.), *Handbook of perception and cognition: Speech, language, and communication* (pp. 181–216). San-Diego: Academic Press.
- Bock, J. K., & Levelt, W. J. M.** (1994). Language production: Grammatical encoding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 945–984). San Diego: Academic Press.
- Bortz, J., Lienert, G., & Boehnke, K.** (1990). *Verteilungsfreie Methoden in der Biostatistik* [Distribution-free methods in biostatistics]. Berlin: Springer Verlag.
- Bosshardt, H.-G.** (1993). Differences between stutterers' and nonstutterers' short-term recall and recognition performance. *Journal of Speech and Hearing Research, 36*, 286–293.
- Bosshardt, H.-G.** (1995, December). *Syntactic complexity, short-term memory and stuttering*. Paper presented at the 1995 ASHA Convention in Orlando, FL.
- Bosshardt, H.-G.** (1999). Effects of concurrent mental calculation on stuttering, inhalation and speech timing. *Journal of Fluency Disorders, 24*, 43–72.
- Bosshardt, H.-G.** (in press). Morpho-syntaktische Planungs- und Kodierprozesse [Morpho-syntactic processes of planning and coding]. In T. Herrman & J. Grabowski (Eds.), *Enzyklopädie der Psychologie: Sprachproduktion* [Encyclopedia of psychology: Speech production]. Göttingen: Hogrefe Verlag.
- Bosshardt, H.-G., & Fransen, H.** (1996). On-line sentence processing in adults who stutter and who do not stutter. *Journal of Speech and Hearing Research, 39*, 785–797.
- Brutten, G. J., & Trotter, A. C.** (1985). Hemispheric interference: A dual-task investigation of youngsters who stutter. *Journal of Fluency Disorders, 10*, 77–85.
- Brutten, G. J., & Trotter, A. C.** (1986). A dual-task investigation of young stutterers and nonstutterers. *Journal of Fluency Disorders, 11*, 275–284.
- Conture, E.** (2000). Dreams of our theoretical nights meet the realities of our empirical days: Stuttering theory and research. In H.-G. Bosshardt, J. S. Yaruss, & H. F. M. Peters (Eds.), *Fluency disorders: Theory, research, treatment and self-help* (Proceedings of the Third World Congress of Fluency Disorders in Nyborg, Denmark; pp. 3–29). Nijmegen: Nijmegen University Press.
- COSMASI.** (February 2001). *Corpus storage, maintenance and access system*. <http://corpora.ids-mannheim.de>
- Ferreira, F.** (1991). Effects of length and syntactic complexity on initiation times for prepared utterances. *Journal of Memory and Language, 30*, 210–233.
- Ferreira, F.** (1993). Creation of prosody during sentence production. *Psychological Review, 100*, 233–253.
- Fodor, J. A.** (1983). *The modularity of mind*. Cambridge, MA: MIT Press.
- Frane, J. W.** (1976). Some simple procedures for handling missing data in multivariate analysis. *Psychometrika, 41*, 409–415.
- Garrett, M. F.** (1990). Sentence processing. In D. N. Osherson & H. Lasnik (Eds.), *Language. Vol. 1: An invitation to cognitive science* (pp. 133–176). Cambridge, MA: MIT Press.
- Gathercole, S. E., & Baddeley, A. D.** (1993). *Working memory and language*. Hillsdale, NJ: Lawrence Erlbaum.
- Goldman-Eisler, F.** (1968). *Psycholinguistics: Experiments in spontaneous speech*. New York: Academic Press.
- Hedges, L. V., & Olkin, I.** (1984). Nonparametric estimators of effect size in meta-analysis. *Psychological Bulletin, 96*, 573–580.
- Helbig, G., & Schenkel, W.** (1973). *Wörterbuch zur Valenz und Distribution deutscher Verben* [Lexicon for the valency and distribution of German verbs]. Leipzig: Verlag Enzyklopädie.
- Herrmann, T., & Grabowski, J.** (1994). *Sprechen. Psychologie der Sprachproduktion* [Speaking. Psychology of speech production]. Heidelberg: Spektrum Akademischer Verlag.
- Howell, P., Au-Yeung, J., & Sackin, S.** (1999). Exchange of stuttering from function words to content words with age. *Journal of Speech, Language, and Hearing Research, 42*, 345–354.
- Howell, P., Au-Yeung, J., & Sackin, S.** (2000). Internal structure of content words leading to lifespan differences in phonological difficulty in stuttering. *Journal of Fluency Disorders, 25*, 1–20.

- Jayaram, M.** (1984). Distribution of stuttering in sentences: Relationship to sentence length and clause position. *Journal of Speech and Hearing Research, 27*, 338–341.
- Johnston, J. R., & Kamhi, A. G.** (1984). Syntactic and semantic aspects of the utterances of language-impaired children: The same can be less. *Merrill-Palmer Quarterly, 30*, 65–86.
- Jorm, A. F.** (1986). Controlled and automatic information processing in senile dementia: A review. *Psychological Medicine, 16*, 77–88.
- Jou, J., & Harris, R. J.** (1992). The effect of divided attention on speech production. *Bulletin of the Psychonomic Society, 30*, 301–304.
- Kadi-Hanifi, K., & Howell, P.** (1992). Syntactic analysis of the spontaneous speech of normally fluent and stuttering children. *Journal of Fluency Disorders, 17*, 151–170.
- Kamhi, A. G., & McOsker, T. G.** (1982). Attention and stuttering: Do stutterers think too much about speech? *Journal of Fluency Disorders, 7*, 309–321.
- Karniol, R.** (1995). Stuttering, language, and cognition: A review and a model of stuttering as suprasegmental sentence plan alignment (SPA). *Psychological Bulletin, 117*, 104–124.
- Kent, R. D.** (2000). Research on speech motor control and its disorders: A review and prospective. *Journal of Communication Disorders, 33*, 391–428.
- Kraemer, H. C., & Andrews, G.** (1982). A non-parametric technique for meta-analysis effect size calculations. *Psychological Bulletin, 91*, 404–412.
- Levelt, W. J. M.** (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
- Lindsley, J.** (1975). Producing simple utterances: How far ahead do we plan? *Cognitive Psychology, 7*, 1–19.
- Logan, K. J., & Conture, E. G.** (1995). Length, grammatical complexity, and rate differences in stuttered and fluent conversational utterances of children who stutter. *Journal of Fluency Disorders, 20*, 35–61.
- Marascuilo, L. A., & McSweeney, M.** (1977). *Nonparametric and distribution-free methods for the social sciences*. Monterey, CA: Brooks/Cole Publishing Co.
- Melnick, K. S., & Conture, E. G.** (2000). Relationship of length and grammatical complexity to the systematic and nonsystematic speech errors and stuttering in children who stutter. *Journal of Fluency Disorders, 25*, 21–45.
- Perkins, W. H., Kent, R. D., & Curlee, R. F.** (1991). A theory of neuropsycholinguistic function in stuttering. *Journal of Speech and Hearing Research, 34*, 734–752.
- Peters, H. F. M., Hulstijn, W., & van Lieshout, P. H. H. M.** (2000). Recent developments in speech motor research into stuttering. *Folia Phoniatica et Logopaedica, 52*, 103–119.
- Postma, A., & Kolk, H.** (1993). The covert repair hypotheses: Prearticulatory repair processes in normal and stuttered disfluencies. *Journal of Speech and Hearing Research, 36*, 472–487.
- Postma, A., & Kolk, H.** (1997). Stuttering as a covert repair phenomenon. In R. F. Curlee & G. M. Siegel (Eds.), *Nature and treatment of stuttering, new directions* (2nd ed., pp. 182–203). Needham Heights, MA: Allyn & Bacon.
- Power, M. J.** (1985). Sentence production and working memory. *Quarterly Journal of Experimental Psychology, 37A*, 367–385.
- Rayner, K., & Pollatsek, A.** (1989). *The psychology of reading*. Englewood Cliffs, NJ: Prentice-Hall.
- Rochon, E., Walters, G., & Caplan, D.** (2000). The relationship between measures of working memory and sentence comprehension in patients with Alzheimer's disease. *Journal of Speech, Language, and Hearing Research, 43*, 395–413.
- Rommel, D.** (2001). Die Bedeutung der Sprache für den Verlauf des Stotterns im Kindesalter [The relevance of psycholinguistic variables on the course of childhood stuttering]. *Sprache Stimme Gehör, 25*, 25–33.
- Rummer, R.** (1996). *Kognitive Beanspruchung beim Sprechen* [Cognitive load during speech]. Weinheim: Psychologie Verlags Union.
- Ryan, B. P.** (1992). Articulation, language, rate, and fluency characteristics of stuttering and nonstuttering preschool children. *Journal of Speech and Hearing Research, 35*, 333–342.
- Schmidt, K.-H., & Metzler, P.** (1992). *Wortschatztest (WST)*. Beltz Test GmbH.
- Scott, W. A.** (1955). Reliability of content analysis: The case of nominal scale coding. *Public Opinion Quarterly, 19*, 321–325.
- Silverman, S. W., & Bernstein Ratner, N. B.** (1997). Syntactic complexity, fluency, and accuracy of sentence imitation in adolescents. *Journal of Speech, Language, and Hearing Research, 40*, 95–106.
- Sussman, H. M.** (1982). Contrastive patterns of intrahemispheric interference to verbal and spacial concurrent tasks in right-handed, left-handed and stuttering populations. *Neuropsychologia, 20*, 675–684.
- Tewes, U.** (Ed.) (1991). *Hamburg-Wechsler Intelligenztest für Erwachsene* [Hamburg-Wechsler intelligence test for adults (HAWIE-R)]. Revision 1991. Bern: Verlag Hans Huber.
- Thompson, A. H.** (1985). A test of the distracting explanation of disfluency modification in stuttering. *Journal of Fluency Disorders, 10*, 35–50.
- Wingate, M. E.** (1988). *The structure of stuttering: A psycholinguistic analysis*. New York: Springer Verlag.
- Yaruss, S.** (1998). Real-time analysis of speech fluency: Procedures and reliability training. *American Journal of Speech-Language Pathology, 7*, 25–37.
- Yaruss, S.** (1999). Utterance length, syntactic complexity, and childhood stuttering. *Journal of Speech, Language, and Hearing Research, 42*, 329–344.

Received October 2, 2001

Accepted May 7, 2002

DOI: 10.1044/1092-4388(2002/068)

Contact author: Hans-Georg Bosshardt, PhD, Fakultät für Psychologie, Postfach 102148, D-4480 Bochum, Germany.
E-mail: hgb@kli.psy.ruhr-uni-bochum.de

Appendix A.

Word pairs for the sentence-generation task

Sg-list training: Wippe - Fuchs, Altar - Puppe, Kreisel - Elefant
[seesaw - fox, altar - doll, top - elephant]

Sg-list 1: Vogel - Sauna, Kugel - Zucker, Scheune - Harfe,
Wolle - Raupe [bird - sauna, sphere - sugar, barn - harp,
wool - caterpillar]

Sg-list 2: Insekt - Palast, Stange - Kaffee, Fabrik - Wiege,
Papier - Ente [insect - palace, pole - coffee, factory - cradle,
paper - duck]

Sg-list 3: Katze - Hotel, Sessel - Wasser, Keller - Fahne, Metall -
Larve [cat - hotel, armchair - water, cellar - flag, metal -
larva]

Word lists for the rhyming decision task

Rh-list training: Haus, Maus, Laus, Motte, Meister, Kleister,
Hund, Schlund [house, mouse, louse, mot, master, glue,
dog, throat]

Rh-list 1: Truhe, Ruhe, Reim, Schleim, Konferenz, Fett, Sonett,
Parkett, Sonne, Meer, Heer [trunk, rest, rhyme, slime,
conference, fat, sonett, parquet, sun, sea, army]

Rh-list 2: Getier, Revier, Qual, Gemahl, Wal, Propeller, Teller,
Welt, Schiff, Pfiff, Tuch [animals, territory, agony, husband,
whale, propeller, plate, world, ship, whistle, cloth]

Rh-list 3: Mantel, Hecke, Verstecke, Schlot, Not, Frisur, Glasur,
Spur, Gehege, Pflege, Bauer [cloak, hedge, hiding-places,
chimney, need, haircut, gloss, trace, enclosure/preserve,
care, farmer]

Rh-list 4: Blume, Pfeife, Schleife, Tasse, Kasse, Grimasse, Durst,
Pfaffe, Giraffe, Hund, Strand [flower, pipe, ribbon, cup,
counter, grimace, thirst, priest, giraffe, dog, beach]

Word lists for the category decision task

Ca-list training: Tiger, Leopard, Klavier, Orgel, Schnaps, Rum,
Wald, Auto, Eisenbahn, Motorrad, Kaktus [tiger, leopard,
piano, organ, booze, rum, forest, car, railroad, motorbike,
cactus]

Ca-list 1: Tasche, Gold, Silber, Platin, Saft, Blau, Rot, Tennis,
Schwimmen, Regen, Schnee [bag, gold, silver, platinum,
juice, blue, red, tennis, swimming, rain, snow]

Ca-list 2: Wein, Bier, Banane, Tanne, Fichte, Buche, Beton,
Tischler, Schlosser, Tulpe, Rose [vine, beer, banana, fir,
spruce, beech tree, concrete, carpenter, locksmith, tulip,
rose]

Ca-list 3: Hai, Limonade, Kakao, Fallschirm, Apfelsine, Birne,
Angst, Wut, Braun, Gelb, Violett [shark, lemonade, cacao,
parachute, orange, pear, fear, fury, brown, yellow, violet]

Appendix B.

The number of propositions expressed in a sentence was determined by propositional analysis comparable to that of Johnston and Kamhi (1984). Propositions are elementary statements about entities or events or relationships between entities. A proposition is composed of a predicate and its argument(s). We distinguish the following types of propositions:

1. A **nuclear proposition** is expressed by the finite verb of a sentence, which is the predicate of the nuclear proposition. For example, [*The bird is sitting*] (sit:bird). In this example one proposition is expressed.

2. An **adverbial proposition** is expressed by an optional prepositional phrase or adverb that does not necessarily belong to the meaning of the verb. For example, [*In the barn one plays harp*] (in the barn:(play:one,harp)). In this example two propositions are expressed. In other cases, a prepositional phrase does not express an adverbial proposition, but is included in the verb frame, for example, local prepositional phrases for verbs of localization (sit in, lie on, stand in), directional prepositional phrases for verbs of locomotion (fly in, fly to, fly over), and transport (put on). A sentence like [*The bird is sitting in the sauna*] (sit in:bird,sauna) expresses only one proposition. Wherever possible the decision about whether

the adverbial proposition is included in the verb frame or not, was based on the valency lexicon for German verbs by Helbig and Schenkel (1973).

3. An **embedded proposition** functions as an argument of the nuclear proposition. It is expressed by an infinitival construction or subordinate clause. For example, [*You can buy coffee*] (can:you,(buy:coffee)). In this example two propositions are expressed.

4. An **associated proposition** has an argument that is co-referential with the argument of some other proposition. It is expressed by an adjective or noun. For example, [*I see a big sugar ball*] (see:I,(ball)+(sugar:ball)+(big:ball)). In this example three propositions are expressed.

5. A **coordinating proposition** has other propositions as arguments and is expressed by a conjunction. For example, [*while I am sitting in a chair I am looking at the water*] (while:(sit in:I,chair), (look at:I, water))). Three propositions are expressed in this example.

6. **Negations** form a proposition of their own. For example, [*A bird doesn't sit in the sauna*] (not:(sit in:bird,sauna)).

