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A test of speech motor control on word level productions: The SPA Test (Dutch: Screening Pittige Articulatie)

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Abstract
The primary objective of this article is to study whether an assessment instrument specifically designed to assess speech motor control on word level productions would be able to add differential diagnostic speech characteristics between people who clutter and people who stutter. It was hypothesized that cluttering is a fluency disorder in which speech motor control on word level is disturbed in high speech rate, resulting in errors in flow of speech and sequencing. An assessment instrument on speech motor coordination on word level was developed and validated. In an elicitation procedure, repetitions of complex multi-syllabic words at a fast speech rate were obtained from 47 dysfluent participants (mean age 24.3; SD 10.25, range 14.2–47.4 yrs) and 327 controls (mean age 25.56 yrs; SD 8.49; age range 14.3–50.1). Speech production was judged on articulatory accuracy, smooth-flow (coarticulation, flow and sequencing) and articulatory rate. Results from people who clutter (PWC) and people who stutter (PWS) were compared to normative data based on control group data. PWC produced significantly more flow and sequencing errors compared to PWS. Further research is needed in order to study speech motor control in spontaneous speech of people who clutter.

Keywords: *Cluttering, stuttering, intelligibility, articulatory accuracy, sequencing.*

Introduction

Successful communication requires the active combination of a range of cognitive and linguistic skills. On the one hand, a speaker must coordinate a range of language-based faculties, including those required to competently formulate and structure sentences. Equally, speech planning and speech production processes are utilized to ensure that language-based elements are produced in an intelligible and coherent manner. Intelligibility itself is related to a number of factors, such as accurate sound production including speech rhythm, stress patterning, and articulatory rate.

It is a well known fact that people who clutter (PWC) experience problems in speech production resulting in unintelligible speech (Daly, 1996; St. Louis, Raphael, Myers, & Bakker, 2003; Ward, 2006; Weiss, 1964). It is hypothesized that cluttered speech occurs when speech rate is too fast for the speech system to handle, or when the person with cluttered speech does not give enough attention to the task of speech production.

Many researchers and clinicians report that people who clutter experience intelligibility problems due to exaggerated coarticulation (deletion of sounds or syllables in multisyllabic words), indistinct articulation (substitution of sounds and/or syllables), and problems in accurate pausing (Bezemer, Bouwen, & Winkelman, 2006; Daly & Cantrell, 2006; St. Louis, Myers, Raphael, & Bakker, 2007; Ward, 2006). Several researchers discuss the fact that although people who clutter experience intelligibility problems in running speech, many are able to produce correct syllable and word structures in controlled situations (Bezemer et al., 2006; Damsté, 1984; St. Louis et al., 2007; Ward, 2006; Weiss, 1964). To produce intelligible syllable or word structures, the speaker must exercise appropriate levels of control over speech motor processes. Riley and Riley (1985) defined speech motor control as the ability to time laryngeal, articulatory, and respiratory movements that lead to fast and accurate syllable production. This ability is implicit in the widely accepted working definition of cluttering by St. Louis et al. (2007) which describes cluttering as:

> A fluency disorder characterized by a rate that is perceived to be abnormally rapid, irregular or both for the speaker (although measured syllable rates may not

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> exceed normal limits). These rate abnormalities further are manifest in one or more of the following symptoms: (a) an excessive number of disfluencies, the majority of which are not typical of people who stutter; (b) the frequent placement of pauses and use of prosodic patterns that do not conform to syntactic and semantic constraints; and (c) inappropriate (usually excessive) degrees of coarticulation among sounds, especially in multisyllabic words. (p.299).

In 1985, Riley and Riley published the Oral Motor Assessment Scale (OMAS). This instrument tests the ability of a speaker to produce intelligible syllable strings at a fast rate. Recent research (van Zaalen, Wijnen, & Dejonckere, 2008) revealed that the performance of adult and adolescent PWC on the OMAS cannot be differentiated from people who stutter (PWS) or controls. PWC experienced no significant difficulties in oral motor coordination at the syllable level. Based on clinical observations in working with people who clutter, it is hypothesized that cluttering is a fluency disorder in which speech motor control at the *word level* is disturbed when speaking at a *fast* speech rate, resulting in errors in the flow and sequencing of speech.

The main purpose of this study was to test whether an assessment instrument specifically designed to assess speech motor control at the word level would be able to differentially diagnose the speech characteristics between PWC and PWS.

Method

Participants

All participants in the PWC and PWS groups were referred to a centre for fluency therapy (between January 2006 and May 2008) in the Netherlands with self-reported fluency problems. Participants were 47 dysfluent persons including 33 males (mean age 24;7, SD 9.8, range 14;4–49;3 yrs) and 14 females (mean age 24;3, SD 10.25, range 14;2–47;4 yrs) and 327 controls including 271 males (mean age 25;5, range 14;1–54;3 yrs) and 56 females (mean age 28;8, range 14;0–46;5 yrs); SD 8.49; age range 14;3–50;1). Participants were divided in three diagnostic groups (PWC, PWS and controls). Diagnostic decision making was based on the objective results of the measurements on articulatory rate, ratio disfluencies, intelligibility, and the score on the Stuttering Severity Instrument (Riley, 1994). Diagnostic decision making procedures are described in detail in van Zaalen et al. (2008). Controls were included in order to obtain normative values on speech motor control at the word level on the SPA test. None of the participants (including controls) reported any neurological or hearing disorders and all were Dutch speaking mono- or bilinguals with an intermediate to high educational level. Participants were tested in the first assessment session prior to therapy or in the case of participants that were already in the course of treatment, (at the most 3 months) before the therapy session began. Adolescent and adult control participants were selected at random from a database of volunteers originating in different parts of the country and who participated in the study. A total of 374 participants participated in the study.

Speech motor control at the word level: The SPA Test

In order to examine the speech motor control on the word level, an assessment instrument was developed. The SPA Test (Dutch: Screening Pittige Articulatie), designed by the first author, is a specially created speech task that provides information on speech motor control and word structure productions at the word level when speaking at fast rates. In an elicitation procedure, three repetitions of ten multisyllabic words at a fast speech rate were obtained. Stimuli were similar to those on the OMAS in that the SPA elicited three words containing (a) mostly bilabial onset consonants (similar to [pʏ]; e.g., Dutch: [ɔpərseremonimestər]), (b) mostly alveolar and velar onsets (as in [tʏkʏ], e.g., Dutch: [vərɑndərəndə ɭevənsɔmstɑndɪxhedən]); or (c) a combination of bilabial, alveolar and velar consonants (as in [pʏtʏkʏ], e.g., Dutch: [ɔnœytsprekələk vɛrveləndə vɛrhɑndəɭɪŋən]). These repetitions were judged on articulatory accuracy, smooth-flow (coarticulation, flow and sequencing), and articulatory rate.

Articulatory accuracy and smooth flow measurements

In order to classify errors in word structure, the SPA Test (Dutch: Screening Pittige Articulatie) was developed (see Appendix 1). Scoring was devised to be consistent with Riley and Riley's (1985) Oral Motor Assessment Screening protocol. In this study, errors were defined within three different categories: (a) Accuracy, (b) Smooth Flow, and (c) Rate. Judgement of errors in sound or syllable production was based on a three point scale: zero errors = 0 points, one to two errors = 1 point, and three plus errors = 3 points. The more errors one produces, the higher the score.

Accuracy

Problems in sound accuracy (distortions or substitutions of voicing and devoicing) were scored. In the Dutch language, substitution of a target sound and the error may not have the same voicing category, as in English (i.e., [θ] → [s]). Accuracy scores for both the PWS and PWC groups that fell more than 1.5 SD above the mean score for the controls were considered to be an indication of problems in adjusting voicing to articulatory movement: an

indicator of difficulty realizing adequate voice-onset time.

Smooth flow

Problems in smooth flow were subdivided into three categories: coarticulation, flow, and sequencing. Coarticulation is the gradual transfer from one speech movement to the next. Errors in coarticulation were: telescoping syllables (i.e., Dutch: [ɔpsermonmestər] instead of [ɔpərseremonimestər]), and within sequence pausing (i.e., Dutch: [ɔpərsere . . . . monimestər]). Flow is the gradual stressing and rhythm of the sequence. Errors, for example, may include changes in the stress pattern for the sequence (i.e., Dutch: [ɔpərsereemonimestər] instead of [ɔpərsere monimestər]). Sequencing errors were scored when a person makes sound order errors between or within syllables (i.e., Dutch: [ɔpərmoniseremestər] instead of [ɔpərseremonimestər]). Total smooth flow scores that were more than 1.5 SD above the mean score of the control group were considered to be an indication of problems in speech motor control at the word level.

Rate

Rate was determined in syllables per second (SPS) by counting the mean time in seconds needed to produce a sequence of three target syllables. Normative comparison data was derived from the controls in this study.

Controls

A reference test of speech motor control at the word level was not available. In order to get normative comparison data on accuracy, smooth flow, and rate, mean results of the non-fluent speakers were determined in z-scores.

Results

Accuracy

A univariate analysis of variance between diagnostic groups corrected with Tukey's-b procedure for unequal group size revealed a significant group difference in Accuracy scores [$F(2,373) = 66.675$, $p < .0001$]. Controls produced a mean of .23 (SD .53) accuracy errors. Controls produced significantly ($p < .0001$) fewer accuracy errors compared to PWC. PWC produced significantly [$F(1,46) = 5.600$, $p = .022$] more accuracy errors compared to PWS (PWC: z-score M 1.65, SD 1.46; PWS: z-score M .67, SD 1.23) (see Tables I–IV, Figure 1).

Smooth flow

An analysis of variance between diagnostic groups on Smooth Flow errors revealed a significant group difference between controls and diagnostic groups [$F(2,373) = 116.460$, $p < .0001$]. Controls produced a mean of 2.04, SD 1.91 smooth flow errors. Controls produced significantly ($p < .0001$) fewer smooth flow errors compared to PWC (z-score M 1.61, SD 1.11) and PWS (z-score M 1.68, SD 1.20). Z-scores of PWS and PWC did not differ significantly [$F(1,46) = .039$, $p = .844$), (see Tables I–IV). A closer examination of the smooth flow scores for the three different categories of coarticulation, flow, and sequencing was done.

Coarticulation

An analysis of variance between diagnostic groups on Coarticulation errors revealed a significant group

Table I. Normative values for Screening Pittige Articulatie (van Zaalen, 2008).

	N	Minimum	Maximum	Mean	Std. Deviation
accuracyABC	327	.00	3.00	.2324	.53220
smoothABC	327	.00	10.00	2.0428	1.91331
coarticscore	327	.00	5.00	.6177	.97076
flowscore	327	.00	3.00	.6177	.72047
sequencescore	327	.00	5.00	.8073	1.11716
rateABC	327	3.1	8.5	5.236	.9189
passcore	327	3.8	16.5	7.511	2.3502

Table II. Results and level of significance of analysis of variance between groups on all part scores on SPA.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
accuracyABC					
Between Groups	48,192	2	24.096	66.675	.000
Within Groups	134,078	371	.361		
Total	182,270	373			
smoothABC					
Between Groups	1010,181	2	505.091	116.460	.000
Within Groups	1609,040	371	4.337		
Total	2619,222	373			
coarticscore					
Between Groups	239,315	2	119.657	88.959	.000
Within Groups	499,027	371	1.345		
Total	738,342	373			
flowscore					
Between Groups	64,855	2	32.428	58.428	.000
Within Groups	205,907	371	.555		
Total	270,762	373			
sequencescore					
Between Groups	142,827	2	71.413	42.121	.000
Within Groups	629,002	371	1.695		
Total	771,829	373			
rateABC					
Between Groups	253,401	2	126.701	81.288	.000
Within Groups	576,707	371	1.559		
Total	830,109	372			
totalSPAscore					
Between Groups	2859,151	2	1429.576	194.267	.000
Within Groups	2730,120	371	7,359		
Total	5589,272	373			

difference [$F(2,373) = 88.959$, $p < .0001$]. Both PWC and PWS produced significantly ($p < .0001$) more coarticulation errors compared to controls. (Coarticulation errors: Controls: M of .617, SD .97; PWC: z-score M .63, SD .68; PWS: z-score M 2.34, SD 2.22). PWS had significant higher Z-scores compared to PWC [$F(1,46) = 15.109$, $p < .0001$] (see Tables I–IV, Figure 2).

Flow

An analysis of variance between diagnostic groups on Flow scores revealed significant group differences [$F(2,373) = 58.428$, $p < .0001$]. (Flow errors: Controls: M .62, SD .72; PWS: z-score M .66, SD 1.33; PWC: z-score M 1.57, SD .85). Both PWS and PWC produced significantly ($p < .0001$) more flow errors compared to Controls. PWC had significant higher Z-scores compared to PWS [$F(1,46) = 8.079$, $p = .007$] (see Tables I–IV, Figure 2).

Table III. ANOVA for people who clutter (PWC) and people who stutter (PWS).

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
zscore accuracy					
Between Groups	10,631	1	10.631	5.600	.022
Within Groups	85,420	45	1.898		
Total	96,051	46			
zscoresmooth					
Between Groups	,051	1	.051	.039	.844
Within Groups	59,191	45	1.315		
Total	59,242	46			
zscorecoarticulation					
Between Groups	32,535	1	32.535	15.109	.000
Within Groups	96,900	45	2.153		
Total	129,435	46			
zscoreflow					
Between Groups	9,074	1	9.074	8.079	.007
Within Groups	50,543	45	1.123		
Total	59,618	46			
zscoresequencing					
Between Groups	11,407	1	11.407	4.782	.034
Within Groups	107,353	45	2.386		
Total	118,760	46			
zscorespascore					
Between Groups	13,565	1	13.565	.536	.468
Within Groups	1137,849	45	25,286		
Total	1151,415	46			

Sequencing

An analysis of variance between diagnostic groups on Sequencing errors revealed a significant group differences [$F(2,373) = 42.121$, $p < .0001$]. Controls produced a mean of .807, SD 1.12 sequencing errors (see Table I). Z-scores of PWS and PWC were significantly different, [$F(1,46) = 4.782$, $p = .034$]. PWS (z-score M .41, SD 1.07) scored according to the controls. PWC (z-score M 1.42, SD 1.77) produced significantly more sequencing errors compared to controls (see Tables I–IV, Figure 2).

Rate

An analysis of variance between diagnostic groups on Rate scores revealed a significant group difference [$F(2,373) = 81.288$, $p < .0001$]. Controls had a mean rate of 5.24, SD .92 seconds for the three words (see Table I). Both PWC and PWS had a significantly slower rate compared to controls (PWC: z-score M 2.83, SD 3.18 and PWS z-score M 2.48, SD 2.10). Z-scores of PWS and PWC were not significantly different, [$F(1,46) = .167$, $p = .685$] (see Tables I–IV).

Total SPA score

An analysis of variance on Total SPA scores between diagnostics groups showed a significant group difference. Controls had a significantly lower total score compared to PWC and PWS [$F(2,371 = 194.267$, $p < .0001$]. PWC (z-score M 9.37, SD 4.69) and PWS (z-score M 8.26, SD 5.54) did not differ significantly on Total SPA

Table IV. Z-scores on sub categories for people who clutter (PWC) and people who stutter (PWS): Minimum, maximum, mean, standard deviation.

	group	N	Minimum	Maximum	Mean	Std. Deviation
PWC	zscore accuracy	29	−.52	3.78	1.6541	1.46190
	zscoresmooth	29	−.25	3.90	1.6096	1.11368
	zscorecoarticulation	29	−.62	1.51	.6266	.67576
	zscoreflow	29	−.90	2.62	1.5682	.85013
	zscoresequencing	29	−.71	4.16	1.4234	1.77168
	zscorerateABC	29	−1.02	9.46	2.8257	3.18358
	zscorespascore	29	1.40	18.96	9.3678	4.68723
PWS	zscore accuracy	18	−.52	2.34	.6757	1.22667
	zscoresmooth	18	−1.01	3.15	1.6775	1.19957
	zscorecoarticulation	18	−.62	5.77	2.3382	2.22438
	zscoreflow	18	−.90	2.62	.6643	1.33520
	zscoresequencing	18	−.71	2.07	.4100	1.07005
	zscorerateABC	18	−.47	6.38	2.4800	2.09718
	zscorespascore	18	−1.97	16.97	8.2626	5.54493

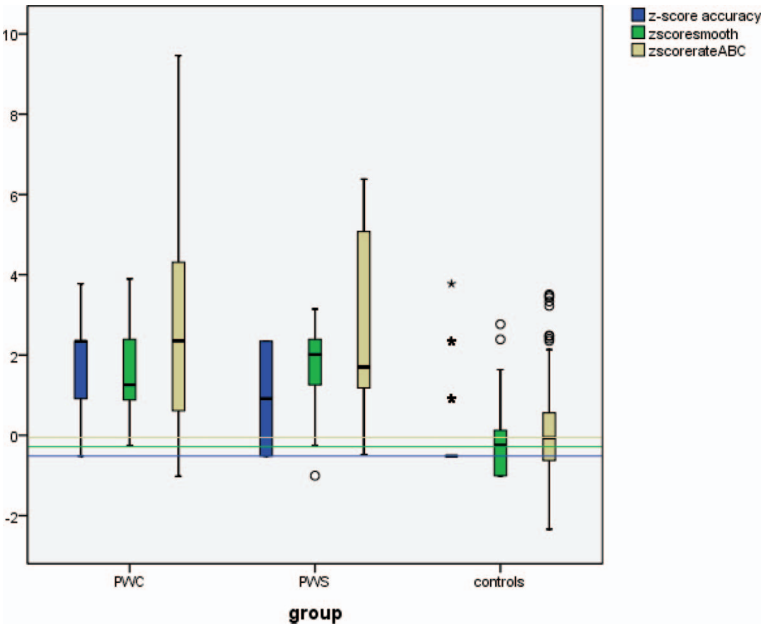

Figure 1. Mean scores on accuracy, smooth flow and rate for people who clutter (PWC) and people who stutter (PWS) and additional normative data and reference lines.

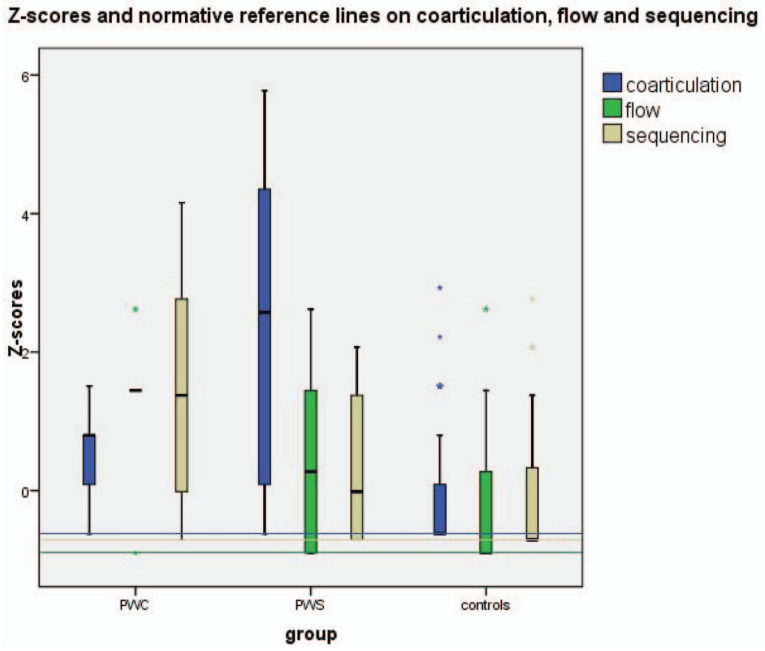

Figure 2. Z-scores and normative reference lines on coarticulation, flow and sequencing. (PWC = People who clutter, PWS = people who stutter).

scores [$F(1,46) = .536$, $p = .468$] (see Tables I–IV, Figure 3).

Discussion

Many researchers have reported intelligibility problems in PWC (Bezemer et al., 2006; Daly, 1996; Dinger, Smit, & Winkelman, 2008; St. Louis et al., 2003; St. Louis, 2007; Ward, 2006). Until now, an assessment instrument for speech motor control at the word-level has not been validated for the dysfluent population. The main purpose of this study was to test whether an assessment instrument specifically designed to evaluate speech motor control at the word level would be able to help differentially diagnose the speech characteristics of persons with cluttered speech and people who stutter. Results indicate that high scores on accuracy, flow and sequencing can differentiate PWC from PWS, but the total score on the Screening Pittige Articulatie (SPA) did not differentiate between persons with cluttered speech and people who stutter.

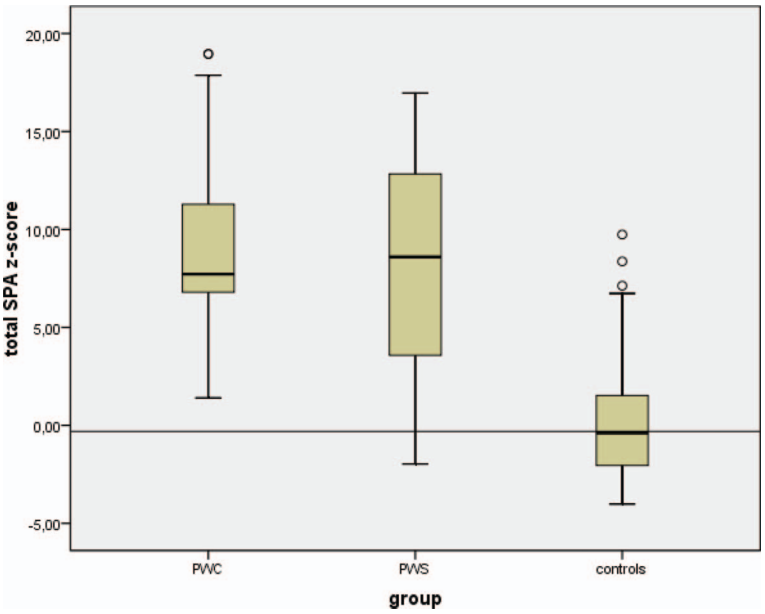

Figure 3. Total SPA z-scores for people who clutter (PWC), people who stutter (PWS) and controls with a normative reference line.

Accuracy scores

Accuracy scores on the SPA for the PWS and PWC groups with more than 1.5 SD above the mean of controls were considered to be indicative of problems in adjusting articulatory movement necessary to realize adequate voice-onset time. In this study, PWC had a mean z-score of 2.40 (SD 1.91) and met the criterion of severe problems in adjusting voicing to articulatory movement, while PWS did not. Problems in adjusting voicing can be seen when the timing demands for planning and execution processes can not meet (Howell, 2004). Target words used in the SPA, with complex phonetic and phonological properties that carry lexical stress, may cause more difficulty than those that do not have these properties (Howell & Dworzynski, 2005). This was evident for PWC.

Smooth Flow scores

Total Smooth Flow scores falling more than 1.5 SD above the group mean of the controls were considered to be an indication of severe problems in speech motor control at the word level. Total smooth flow scores appeared to be of no significant value in differentiating between the PWC and PWS.

Coarticulation

In developing the assessment protocol, we replicated the major judgements categories used in the OMAS to the SPA. In the Oral Motor Assessment Scale (Riley & Riley, 1985) protocol, a major category named ''coarticulation'' contains both telescoping of syllables and extra pausing. Because people who stutter produced frequent extra pauses between and within words, their score on coarticulation was high. On the other hand, persons with cluttered speech produced frequent telescoping errors, while people who stutter rarely telescoped syllables. In combining pausing and telescoping data within the coarticulation category, potential difference might have been masked in the overall analysis. In future versions of the SPA, it is recommended that telescoping and pausing errors be split into two categories.

Flow and Sequencing scores

Scores on flow and sequencing errors differentiated the PWC from controls and PWS. Flow and sequencing abilities can be disturbed when speech planning has to be performed within small time limits. In the SPA, participants had to repeat test words at a fast speech rate. Goberman and Blomgren (2008) reported that PWS exhibited significantly more stuttering on variable rate tasks than on habitual rate tasks. Rieber, Breskin and Jaffe (1972) reported that PWS tend to have greater mean pause times and lower mean phonation times than persons with cluttered speech. In a fast rate, pause time is reduced, resulting in a higher frequency of flow and sequencing errors in the PWC group and a longer phonation time in the PWS group. People who stutter produced extra pauses that disturbed their flow of speech, but the syllable order was not disturbed.

PWC produced a high number of errors in a rate perceived to be fast, but not statistically different from the people who stutter. It is suggested that the accuracy and smooth flow problems in PWC negatively influenced their intelligibility. It is further suggested that articulatory rate in the PWC, although measured within normal limits, is perceived to be abnormally fast as a side-effect of other issues

relating to problems in speech motor planning and speech motor execution (St. Louis et al., 2007; van Zaalen et al., 2008). As Ward (2006) described, PWS seem to have problems producing what is already coded, while PWC experience problems in coding speech during conversation.

Total SPA score

The Total SPA Score was calculated by the summation of accuracy errors, smooth flow errors, and rate scores. The total SPA score for PWC and PWS was negatively influenced by speech rate. The total SPA score appeared to be of no value in the differential diagnosis within the dysfluent population. This can be explained by the high scores for PWS in some categories and high scores for PWC in other categories. Both PWC and PWS experienced difficulties with speech motor skills.

Although this study has presented some new insights in the speech motor control in persons with cluttered speech or people who stutter, further research is needed in areas of spontaneous speech and other diagnostics groups that are related to speech motor planning or execution problems.

Speech motor control at word level

"Speech will be fluent if execution time for the segment currently being produced is sufficiently long for the plan for the following segment to be ready, after the current segment has been executed" (Howell & Dworzynski, 2005, p. 352). Fluent speech needs separately planning and execution components (Levelt, 1989). Speakers can start an utterance (execution) before they have the complete plan (Kolk & Postma, 1997). When execution is getting ahead of planning, fluency problems arise. In testing speech motor at word level (multisyllabic words) at a fast rate planning time was shortened. While PWC experienced accuracy, flow and sequencing errors as a result of that, it can be assumed that planning problems underlie PWC production problems. While PWS experienced mainly coarticulation problems, it can be assumed that execution problems underlie PWS production problems. Further research is needed to confirm this finding.

Conclusion

The main purpose of this study was to answer the question whether an assessment instrument especially designed to assess speech motor control at the word level would be able to differentially diagnose speech characteristics of persons with cluttered speech and people who stutter. Results show that smooth flow scores differentiate PWC from PWS. Persons with cluttered speech produced significantly more flow and sequencing errors compared to the people who stutter. In addition, people who stutter produced significantly more errors on coarticulation compared to persons with cluttered speech and controls. Overall, the total score on the SPA test served to differentiate between fluent and dysfluent participants. The SPA test on speech motor control on word level productions differentiated persons with cluttered speech from people who stutter.

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Appendix. Test protocol.

Screening Pittige Articulatie (SPA) van Zaalen, 2008

This assessment can produce insight into speech motor skills on word level within test circumstances. Often test words, only the three bold printed words are analysed on accuracy, smooth flow and articulatory rate.

Instructions: The client can look at the word to produce for 5 seconds maximum. The word is covered and subsequently the client may repeat the words 3 times in consecutive syllable strings, in a fast but still intelligible way and without pauses.

Words (Dutch):
periodieke uitkeringen = letterlijk en figuurlijk = veranderlijke wind uit westelijke richtingen = **onuitsprekelijk vervelende verhandelingen** = woordelijke aanhalingen = geldelijke tegemoetkoming = **opperceremoniemeester** = onverantwoordelijke elementen = **veranderende levensomstandigheden** = maatschappelijke verhoudingen

Naam:

Mean number of errors in three attempts is determined and pointed out. Error score is pointed out in the row directly below.

	Accuracy						Smooth Flow								
	Distortion			Voicing			Coarticulation			Flow		Sequencing			
Word set															Rate in SPS
Opperceremonie-meester	0	1–2	3+	0	1–2	3+	0	1–2	3+	yes	no	0	1–2	3+	Sec. A
Error score	0	1	3	0	1	3	0	1	3	0	1	0	1	3	
Veranderende levensomstandigheden	0	1–2	3+	0	1–2	3+	0	1–2	3+	yes	no	0	1–2	3+	Sec. B
Error score	0	1	3	0	1	3	0	1	3	0	1	0	1	3	
Onuitsprekelijk vervelende verhandelingen	0	1–2	3+	0	1–2	3+	0	1–2	3+	yes	no	0	1–2	3+	Sec. C
Error score	0	1	3	0	1	3	0	1	3	0	1	0	1	3	
Total score															A+B+C = sec
Z-score															
Overall score															