ORIGINAL ARTICLE

Attentional functions in speech fluency disorders

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This study focused on attentional functions in fluency disorders. Nine persons who stuttered, eight persons who cluttered, and nine fluent controls, executed a set of attention tasks while psychophysiological indices of activation (heart rate variability and skin conductance) were recorded. The results indicated that the stutter group had a significantly longer response time on the Posner Test of Covert Attention Shifts than the other two groups, and the effect was most obvious when the target appeared in the right visual field. There were no significant differences between groups in the physiological activation as measured by heart rate, skin conductance and heart rate variability. The present results support the hypotheses that stuttering may be associated with impaired skills to focus attention, while cluttering did not seem to be associated with impaired focused attentional skills. However, the sample available within the study period was limited, and due to small samples care should be taken before making firm conclusions.

Key words: attention, cluttering, heart rate variability, skin conductance, stuttering.

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INTRODUCTION

Fluency disorders

The most common fluency disorders are stuttering and cluttering. There has not as yet been any agreement about the aetiology of stuttering, but different definitions have reflected the different viewpoints of researchers. Stuttering has been described as an exceptionally complex phenomenon linked to genetics (2) (Yari, Ambrose & Cox, 1996), neurology (De Nil *et al*., 2000) (25), physiology (30) (McFarlane & Prins, 1978) (58), and psychological factors (7, 8, 12). A prevalence of less than 1% is often quoted (45). Cluttering is estimated to affect about 1.5% of the population (3).

Stuttering

Three aspects are commonly included in definitions of stuttering: language behaviour (45, 46, 57), emotional functions (6, 7, 37, 48), and communicative skills (6).

The language behaviour aspect is observable during speech. Speech repetitions, sound prolongations, and articulatory blocks characterize stuttering (24, 49, 57),

Electroencephalographic and functional imaging studies of the brain indicate deviant activation patterns in stutterers as compared to non-stutterers (Braun *et al*., 1997; De Nil *et al*., 1995) (35, 36, 24). While non-stutterers tend to activate predominantly left hemispheric brain structures when speaking or reading, stutterers show less left hemispheric activation and more activity in the same areas of the right hemisphere (Braun *et al*., 1996; De Nil *et al*., 1995) (24). The emotional aspect of stuttering implies that the person is emotionally influenced, in varying degrees, by the stuttering. Measures of physiological arousal such as heart rate variability and skin conductance have been used to assess whether people who stutter are more anxious than those who do not stutter. Cognitive stress combined with demands on rapid speech resulted in more speech interruptions and significantly higher levels of arousal in persons who stutter than in persons who do not stutter (10, 43). Other researchers have not found any psychophysiological differences between people who stutter and fluent speakers (32, 59).

The communicative aspect emphasizes that stuttering occurs only in communication with others and may thus create interference (6, 23, 12). Each of these three aspects can only partially describe the nature of stuttering.

In the present study, stuttering is defined as a disorder of fluency of speech, including repetitions,

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prolongations and blocks, accompanied by increased muscular tension, which may cause a reaction in the subject, leading to disrupted communication (24, 45).

Cluttering

Cluttering has typically been described as impaired speech, characterized by rapid or irregular speech rate, omissions and inversions of sounds, syllables and words (29), or as a disorder of fluency, timing and articulation (38, 39). Definitions of cluttering describe both articulatory and linguistic aspects as major characteristics (St. Louis et al., 1985) (18). Cluttering is probably due to a neurological dysfunction (16).

Cluttering is also described as a language disorder (18, 61). Cluttering is usually not accompanied by fright or fear, or identification of problems with specific words or sounds. A person who clutters does not perceive the speech as deviant (61). The emotional aspect will usually be different for a person who clutters compared with a person who stutters. Whereas a person who clutters is unconcerned about his own speech, a person who stutters would be self-conscious and worried about what others would think of him (61). However, these assumptions are based on clinical experience, not on systematic empirical studies.

The two dysfluency groups differ when analysing the communicative aspect. A person who clutters manages communication skills better under pressure than in a relaxed environment, and is more fluent after an interruption than a person with stuttering (61). Pragmatic perspectives on cluttering indicate that persons with cluttering frequently manifest pragmatic errors and communication failures, compared to normal speakers (54). This may be associated with poor linguistic skills or inattention during the planning of a speech action (61).

Cluttering has been a neglected area in the field of speech and language research (Meyers, 1992). This may be due to its multifaceted and complex nature (Meyers & St. Louis, 1992). Cluttering occurs as a single symptom or combined with stuttering. Two cluttering subgroups have been identified (54): classical cluttering, where the motor aspect in speech is the primary deficit, and cluttering as a part of a syndrome.

This supports the hypothesis that cluttering is due to an organic anomaly in the central nervous system (45, 61).

In the present study, cluttering was defined as a disorder of fluency, timing, articulation and language. Communication failures associated with impaired attention and poor linguistic skills are also included in the definition of cluttering in this study. For cluttering assessment the 'Cluttering Symptoms Summary Checklist' (Daly & Burnett, 1996) was used. The checklist is an assessment tool containing items researchers believe to be indicative of cluttering (Daly, 1996; St. Louis, 1992) (61), but it is not intended to be an instrument used for research purposes (Daly, 1996).

Attention

Attention is a complex process involving different functions and areas in the brain. Mirsky (33) proposed a model for attention involving five distinct functions: the capacity to focus/execute, to encode, to shift, to sustain and to stabilize attention. The focus/executive function involves the ability to select relevant stimuli from a broad array of stimuli and carry out the task in an effective way. The shift functions involve the ability to change focus in a flexible way. Sustained attention is defined as vigilance or the capacity to maintain focus over time. The focus/executive function is mainly associated with the frontal regions of the brain, the superior-parietal and temporal areas, as well as parts of the basal ganglia. Encoding is associated with the hippocampus and the amygdala. The ability to shift attention relates to structures of the dorso-lateral prefrontal cortex, while the ability to sustain attention is associated with functions in the thalamus and the reticular substance. This organization of the 'attention system' implies both specialization and interaction. In the present study three of these functions were assessed: the sustain function, the shift function and the focus/executive function.

Attention is associated with physiological activation, and activation can be studied by looking at differences in heart activity and skin conductance during rest and under cognitive demand (27). Also, physiological activation may have implications for attention (27). Brief changes in heart rate typically follow significant events that involve shifts of attention. Focusing of attention usually involves mental effort, and the allocation of 'executive' processing increases blood flow for processing the attended events (27, p. 228). Attention at a higher cognitive level involves the control of behaviour and actions of judgement, of the ability to use feedback to alter strategies, and self-regulation (56).

Studies have been carried out around single cognitive functions in fluency disorders (5, 10, 34 60), but so far no one has presented data from a diversity of attention-tests, controlling for physiological activity with persons with fluency disorder.

Based on the stutterers' awareness of others' reactions to their speech it may be expected that stutterers have a better ability to shift attention than clutterers (cp. 45, 61). However, a better ability to sustain attention may be seen in clutterers compared to stutterers based on a general observation that they cope better under pressure and are unconcerned with their speech problems (cp. Meyers & St. Louis, 1992) (61).

The hypotheses in the present study were: 1) subjects who stutter have a better ability to shift attention than to focus and sustain attention, compared to subjects who clutter and a control group; 2) subjects who clutter have a better ability to focus and sustain attention than to shift attention, compared to persons who stutter and a control group; 3) based on the assumption that speech would provide more discomfort to a person who stutters than to a person who clutters, we expect to see differences in activation as measured by heart rate variability between the two groups with fluency disorders; 4) attentional efficacy was expected to be explained by variations in activation.

METHOD

Subjects

The dysfluency group consisted of 17 subjects (aged 9–17 years), referred by the local psychology agencies for assessment and counselling, and further referred to a regional logopedic clinic. Stutterers were assessed by the differential-diagnostic model of Ainsworth 1977, and the clutterers were assessed by the 'Cluttering Symptoms Summary Checklist' (Daly, 1996). This made two subgroups: 9 stutterers (ST) (aged 11–15, mean age 13.41 (SD 1.76); 6 males and 3 females), and 8 clutterers (CL) (aged 9–17, mean age 13.88 (SD 2.88); 6 males and 2 females). The control group (Con) consisted of 9 subjects (aged 11–16, mean age 13.64 (SD 1.90); 6 males and 3 females) who were matched in age and gender with the dysfluency groups. Criteria for inclusion were: normal intellectual abilities as defined by full scale IQ (FIQ) >70, with either verbal IQ (VIQ) >80 or performance IQ (PIQ) >80 cp. (21) no records of need for special needs education; no neurological impairments; normal visual and auditory functions and Norwegian as their first language. There were significant differences between the cluttering group and the control group according to VIQ ($p < 0.05$), PIQ ($p < 0.12$) and FIQ ($p < 0.006$), where the cluttering group showed the lowest scores. Descriptive data are shown in Table 1.

Experimental tests

The following tests of attention were applied:

The Posner Test of Covert Attention Shift (44) consists of the sub-tests Endopos, and Exopos. Endopos has been described as measuring controlled attention, while Exopos measures automatic and stimuli-driven shifts of attention. The test was administered on a computer screen showing a central location cross and two peripheral boxes. Throughout the trials, the subjects had to fixate the eyes on the central location. The target, to which the subjects were to respond, appeared after an interval of varied time. The subjects were instructed to press a key on the keyboard when a cue appeared. Two types of trials were given: valid trials in which the cue correctly predicted the location of the subsequent target, and invalid trials, in which the cue incorrectly predicted the location of the subsequent target. The dependent variable was mean response time in milliseconds.

Conners Continuous Performance Test (CPT), (11) was used for measures of sustained attention. The subjects were instructed to press a key on the keyboard when a letter was presented on the screen. The dependent variables were the number of times the subject correctly responded to the stipulated letter (K) stimulus on the computer screen (correct), the number of missed stimuli (omissions), the number of responses to other letters (commissions) and mean response time (ms).

The Dichotic Listening Test (DL, DLCV-108), (28) is an auditory test commonly applied to assess language lateralization, sustained attention and the ability to shift attention. The subjects were given tasks with two conditions: 1) non-forced attention, where the task of the subject was to repeat what he or she heard best; 2) forced attention where attention was

Table 1. *Descriptive data for the stuttering group (ST), the cluttering group (CL), and the control group (con)*

Group	$N=26$ N	Age Mean (SD)	Gender male/female	Hand- preference: right/left	VIQ WISC-R Mean (SD)	PIQ WISC-R Mean (SD)	TIQ WISC-R Mean (SD)
ST	9	13.41 (1.76)	6/3	8/1	108.66 (16.49)	102.11 (14.41)	106.55 (12.75)
CL	8	13.88 (2.88)	6/2	8/0	103.87 (18.53)	93.37 (10.04)	98.75 (11.81)
Con	9	13.64 (1.90)	6/3	8/1	120.00 (12.74)	108.88 (10.24)	116.11 (11.36)

Note: WISC-R = Wecheler Intelligence Scale for Children–Revised; VIQ = Verbal IQ; PIQ = Performance IQ; FIQ = Full IQ.

directed to the right ear (FR) or to the left ear (FL), balanced between subjects. The test was administered and scored according to the instructions given in (28). Compared to the former procedures, DLCV measures auditory attention as opposed to visual attention.

The Stroop Color Word Test (SCWT), (22, 53), Norwegian version Hugdahl, no date was used to measure the shift function. The test consists of 48 items for each of the three tasks of 'color' naming (C), 'word' reading (W) and 'color/word' naming (CW), presented in fixed order, and analysed separately for speed (s) and correct responses (cr).

The Wisconsin Card Sorting Test (WCST), (4), WCST-CV2, (26) was used to assess the focus/execute function. The following six variables were examined in this study: total numbers of 1) cards administered (TA), 2) errors (TE), 3) perseverative responses (PR), 4) categories completed (CC), 5) perseverative errors (PE), and 6) non-perseverative errors (NPE) (see Table 2).

All tests are widely used clinically and in international neuropsychological research.

Heart rate (HR), heart rate variability (HRV) and skin conductance level (SCL) were measured with the Ambulatory Monitoring System (AMS36; Vrije Universität, Department of Psychophysiology). Psychophysiological activation was measured during rest and during attentional testing.

HR was recorded as beats per minute, measured as the interval in milliseconds between each successive R-wave (the R-R interval). SCL was recorded as level of conductance in micro-Siemens (μS). In addition, the root mean of squared successive differences (MSSD) between each heartbeat was calculated and used as a measure of HRV see e.g. (55).

Design and statistical analysis

Data from the tests were analysed by using descriptive statistics and analyses of variance (ANOVA). Initial analyses were based upon the raw-scores from the different tests in a Group (3: ST, CL, Con) by Task mixed design. The alpha level was set to $p < 0.05$. Significant main effects and interactions were followed up with Fisher's Least Significant Difference (LSD).

RESULTS

Cognitive tests

WISC-R yielded significant differences between the cluttering group and the control group both on VIQ, PIQ and TIQ.

Analyses of variance of the performance on DL, SCWT, WCST and CPT yielded no significant differences between the groups. However, there was a

Table 2. *Mean (SD) for the stuttering, cluttering and control groups of the Dichotic Listening Test, the Stroop Color Word Test and the Wisconsin Card Sorting Test*

Attentional tests	Control, $N=9$ Mean (SD)	Stuttering, $N=9$ Mean (SD)	Cluttering, $N=8$ Mean (SD)
DL NF RE	12.00 (3.39)	12.55 (2.92)	13.37 (4.13)
DL NF LE	10.66 (1.93)	10.00 (3.31)	9.12 (2.41)
DL FR RE	17.88 (3.65)	17.11 (4.45)	16.75 (4.65)
DL FR LE	8.22 (2.63)	8.88 (3.65)	7.37 (2.26)
DL FL RE	14.00 (4.27)	13.66 (4.35)	13.25 (3.32)
DL FL LE	11.88 (5.46)	11.44 (4.21)	10.12 (2.47)
DL zASI	0.94 (1.61)	0.82 (1.15)	0.86 (1.23)
DL zLAMBDA	0.24 (0.71)	0.54 (0.98)	0.83 (1.05)
Stroop C–RT	35.11 (9.59)	47.88 (27.55)	37.12 (14.59)
Stroop W–RT	19.88 (3.10)	24.00 (2.87)	30.00 (23.30)
Stroop CW–RT	61.55 (19.11)	75.11 (21.04)	64.62 (16.80)
Stroop INT–RT	49.05 (18.19)	59.91 (21.04)	48.46 (11.60)
WCST TE	29.88 (24.52)	30.66 (12.83)	41.25 (20.31)
WCST Persev. Errors	11.55 (7.50)	11.88 (6.27)	18.12 (11.33)
WCST NE	18.33 (17.24)	18.77 (9.58)	23.12 (11.33)
WCST CC	5.11 (1.76)	5.55 (0.72)	5.12 (1.45)
WCST FMS	0.77 (0.66)	1.00 (1.50)	0.87 (1.24)

Note: DL = dichotic listening; NF = non-forced; FR = forced right; FL = forced left; RE = right ear; LE = left ear; DL zASI = standardized score of Attentional Shift Index; zLAMBDA = standardized LAMBDA score; Stroop = Stroop Colour-Word Test; C = colour-naming task; W = colour-word reading; CW = colour/word; RT = response time in seconds; WCST = Wisconsin Card Sorting Test; TE = total errors; NE = non-perseverative errors; INT = interference scores; FMS = failure to maintain set; CC = categories completed.

Table 3. *Mean (SD) of the Conners Continuous Performance Test (CPT)*

CPT	Control, $N = 9$ Mean (SD)	Stuttering, $N = 9$ Mean (SD)	Cluttering, $N = 8$ Mean (SD)
CPT Target hits 1.t	36.00 (17.84)	48.44 (11.94)	47.50 (12.45)
CPT Target hits 6.t	33.00 (16.18)	47.11 (11.28)	46.25 (11.85)
CPT Total omissions 1.t.	2.00 (1.87)	1.55 (1.94)	2.00 (1.85)
CPT Total omissions 6.t.	5.00 (7.41)	2.8 (3.05)	3.25 (3.45)
CPT Non-target rejections 1.t.	1.22 (1.20)	1.11 (0.78)	1.75 (1.16)
CPT Non-target rejections 6.t.	1.33 (1.22)	1.22 (1.39)	1.87 (1.12)
CPT Non-target commission 1.t.	3.00 (1.73)	4.44 (1.50)	3.72 (1.16)
CPT Non-target commission 6.t.	2.88 (1.90)	4.33 (1.87)	3.62 (1.50)
CPT Overall reaction time. 1.t.	292.22 (41.80)	312.33 (38.53)	308.37 (41.65)
CPT Overall reaction time 6.t.	381.44 (58.68)	349.66 (91.32)	368.25 (70.19)

Note: 1.t = Trial number 1; 6.t = Trial number 6.

tendency to higher error rate in the cluttering group on the WCST (see Tables 2 and 3). These tendencies should be further exploited in a larger sample.

Posner Test of Covert Attention Shift

Figure 1 depicts the performance on the two subtests of the Posner Test of Covert Attention Shift separately for the three groups. The performance on the tests was analysed by a four-way ANOVA with Group (3: Con, ST, CL) × Test (2: Exopos, Endopos) × Cue (3: Valid, Invalid, No Cue) × VF (Visual Field) (2: Right Field, Left Field). The analysis yielded a significant Group by Test interaction, $F(4, 46) = 13.73$, $p < 0.001$. Fisher's LSD follow-up test showed that this was due to the stutterers having longer response time in Endopos ($p < 0.008$) and Exopos ($p < 0.01$) compared with clutterers ($p < 0.008$ and $p < 0.01$, respectively). The controls showed shorter response time in Endopos than the two other groups ($p < 0.05$) There was also a

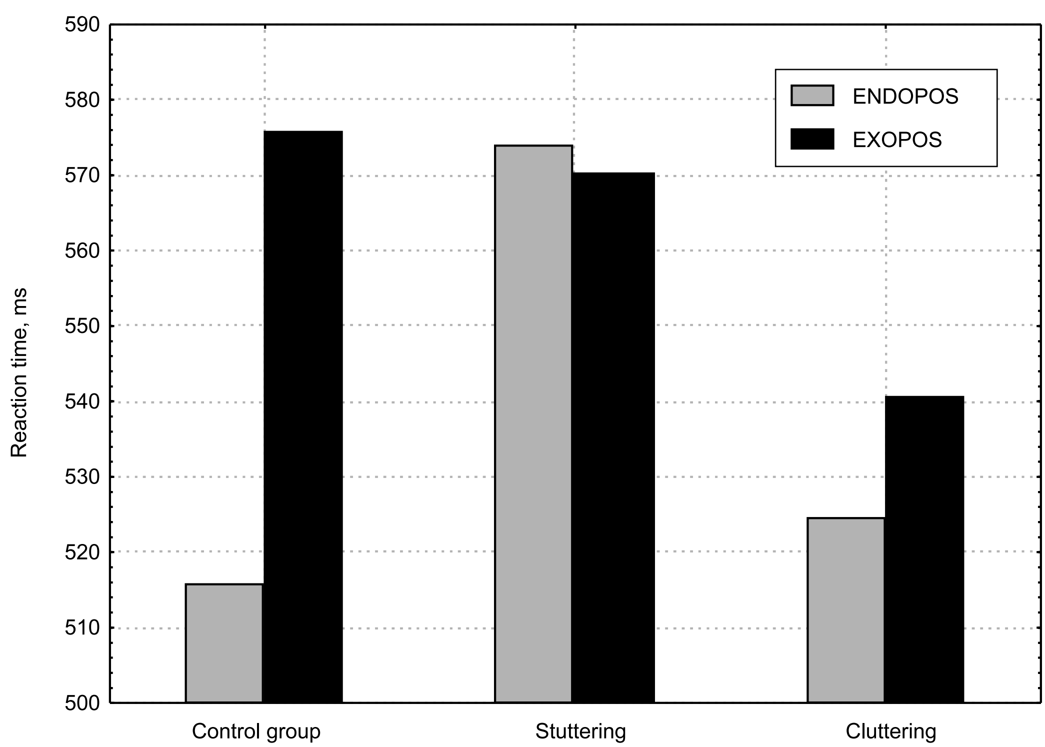

Fig. 1. Response time in ms on the Posner tests Exopos and Endopos separated for the control group, the stuttering group, and the cluttering groups

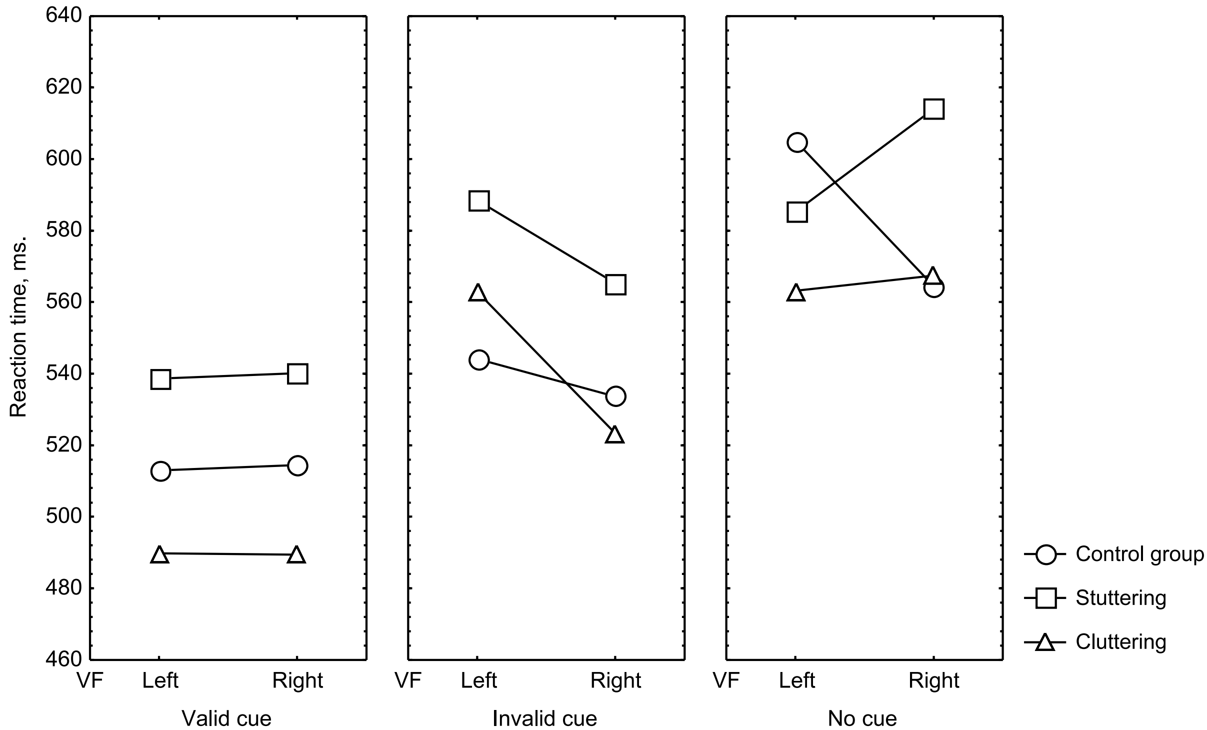

Fig. 2. Response time in ms on the Posner test of covert attention shift. Response time is depicted separately for groups, cues and visual field

significant Group by Cue by VF interaction, F(4, 46) = 2.65, $p < 0.04$. Follow-up with LSD test showed that all groups used shorter response time on Valid *versus* No cue ($p < 0.001$), but also that stutterers used longer response time compared to the two other groups on No Cue condition when the targets were presented in the right visual field compared to the left (see Fig. 2).

The Conners Continuous Performance Test

Two-way ANOVA with a Group (3: Con, ST and CL) × Task (5: target hits, total omissions, non-target rejections, non-target commissions and overall reaction time) yielded no significant effects.

Psychophysiological measurements

Heart rate, skin conductance and heart rate variability measures are shown in Table 4. Three one-way ANOVAs, with Group (Con, ST and CL) as independent variable and recorded values for each of the three measures HR, SCL and MSSD as dependent variables, revealed no significant differences between the groups as to psychophysiological measurements.

DISCUSSION

In this study it was hypothesized that there would be differences in attentional functions between stutterers and clutterers. This was partially confirmed. The results showed that subjects who stutter used significantly longer time on the subtest Endopos of the

Table 4. *Means and standard deviations (SD) for heart rate, skin conductance and heart rate variability*

	Control ($N = 9$) Mean (SD)	Stuttering ($N = 8$) Mean (SD)	Cluttering ($N = 7$) Mean (SD)
Heart rate	83.33 (11.53)	82.29 (10.18)	81.97 (8.16)
Skin conductance	14.91 (5.36)	13.91 (3.76)	9.30 (3.77)
Heart rate variability	50.22 (17.23)	54.36 (20.21)	72.91 (37.33)

Note: Heart rate variability measured as MSSD (mean squared successive differences of RR-intervals).

Posner Test of Covert Attention Shift, which measures controlled attention, compared to persons who clutter and the control group. Subjects who stutter also showed a significantly longer response time on the Posner Test of Covert Attention Shift, compared to the other groups, when the target appeared in the right visual field, and no cue was given. This means that stutterers used more time demanding internally driven shift of attention prepared in the left hemisphere than did the other groups. This may imply impaired processing of stimuli that is directed towards the right perceptual field/left hemisphere in lateralized cognitive tasks.

Stuttering seems to occur when the neurophysiological system that integrates motor, linguistic and cognitive processes, fails (9) (Curlee & Siegel, 1997; De Nil, Kroll, Kapur, & Houle, 1995) (24, 46 p. xvii).

One may speculate that persons who stutter become more emotionally involved when speaking, and therefore the right hemisphere becomes automatically activated (13, 15). Another hypothesis is that hemispheric differences point to an underlying predisposition for a rhythm dysfunction in people who stutter. These findings in brain activity have not yet resulted in any unifying theory of stuttering. This may indicate an increased activation of right hemisphere in persons who stutter, resulting in interference in the processing of stimuli directed to the left perceptual field/right cerebral hemisphere.

Subjects with cluttering showed significant shorter response time on the subtest Exopos, which measure automatic and stimuli driven shifts of attention, compared to people who stutter and controls. This may support the hypothesis that clutterers are more impulsive, unconcerned, impatient, forgetful and hectic than stutterers (45, 61). It is open to discussion whether the impaired scores are due to impaired attentional functions.

No significant differences between the groups were seen on the Conners Continuous Performance Test, the Dichotic Listening Test, the Stroop Color Word Test or the Wisconsin Card Sorting Test. However, interference scores on the SCWT was slightly higher in stutterers compared to clutterers and controls, which was expected based on earlier findings (9) (De Nil, Kroll, Kapur, & Houle, 1995) (24, 46), although the differences did not reach a significant level. A tendency towards a higher error rate in the Wisconsin Card Sorting Test in the cluttering group was also seen. No significant between-group differences were seen in physiological activation as measured by skin conductance level and heart rate variability, lending support to earlier studies (32, 43, 60).

These tendencies are comparable with studies indicating reduced ability to steer movements in the desired direction following stuttering (10). Meta-studies have shown that people who stutter have significantly slower reaction times in starting and stopping their voice, compared to fluent speakers (De Nil, Kroll, Kapur, & Houle, 1995) (24).

The present results support the hypothesis that stuttering may be associated with impaired focused attentional skills as seen by Posner, and that cluttering may be associated with impaired executive functions as seen by tendencies in the Wisconsin Card Sorting Test.

The study of attention and psychophysiological measurements in subjects who stutter and subjects who clutter, is a relatively new area, and although skin conductance studies in subjects with stuttering have been performed for many decades see e.g. (32, 43, 47), the studies are inconclusive and contradictory. The implications from our study are that differences in cognitive and perceptual processing are visible in speech fluency disorders that may reflect reduced left hemisphere activation and increased right hemisphere activation associated with stuttering.

The cluttering group showed reduced response time in an automatic and stimuli-driven form of attention, indicating impulsiveness and impatience. This was shown by the Posner Test, and underlined by tendencies seen in the Wisconsin Card Sorting Test.

This study includes several new approaches to the investigation of speech fluency disorders. According to Meyers 1992, cluttering has been a neglected area in fluency research. However, the sample available within the study period was limited and the study must therefore be characterized as a pilot study. Due to the small groups, the statistical analyses should be seen as preliminary, and the results need to be confirmed in a larger sample before making firm conclusions. Further studies will be needed.

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