

## REDUCTION IN STUTTERING BY DELAYED AND FREQUENCY SHIFTED AUDITORY FEEDBACK: EFFECTS OF ADAPTATION AND SEX DIFFERENCES

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### INTRODUCTION

The acoustic perturbation technique, by which the original acoustic speech signal is artificially modified and then fed back via headphones, can enhance fluency in people who stutter. An effective and well known method is the delayed auditory feedback (DAF) of the speech signal. With long delay intervals above 100 msec DAF leads to a prolongation of vowels and a characteristic speech rhythm („DAF voice“). But also short delay intervals between 50 and 100 msec are effective in reducing stuttering (Lotzmann, 1961), although changes in speech production are not necessarily perceivable by a listener (Natke, 2000). Studies using intermittently delayed auditory feedback while speaking test words repeatedly, reveal that especially vowels of long stressed syllables will be prolonged, whereas unstressed syllables remain almost unaffected (Kalveram & Jäncke, 1989). These prolongations occur with delay intervals below 40 msec not reaching the perceptual threshold. Wingate (1970) suggested, that in delayed auditory feedback as well as other strong fluency enhancing conditions, a modified vocalization leads to the fluency enhancing effect. This view was criticized by other authors (Armson, Kalinowski & Stuart, 1995).

Since the 1980's the effectiveness of frequency shifted auditory feedback (FAF) with different shift magnitudes could be shown (Howell, El-Yaniv & Powell, 1987; Kalinowski et al., 1993). Especially studies, in which subjects had to speak spontaneously instead of reading, revealed a great variability in the fluency enhancing effect between subjects (Ingham, 1997; Armson & Stuart, 1998). However, FAF is able to enhance fluency in people who stutter. As for DAF the underlying processes of the fluency enhancing effect of FAF have not been identified yet. Under FAF, people do not show prolonged speech as under DAF with long delay intervals, and studies using an intermittent frequency shifting do not reveal prolongation of vowels and report only small compensation effects regarding fundamental frequency (Natke & Kalveram, submitted; Natke & Kalveram, this volume). Thus it seems unlikely that changes in speech production lead to the fluency enhancing effect of FAF.

An analogy to the fluency enhancement by FAF could be seen in what Bloodstein (1995) calls the “Masquerade Effect”: If people who stutter alter the way they speak in a manner, that sounds strange to them, their stuttering is reduced. There is clinical evidence that after prolonged use of such novel modes of speaking, the effectiveness decreases. This indicates, that the novelty and, therefore a shift of attention operates. There is an obvious strangeness of the speech signal fed back when shifted in frequency. Armson and Stuart (1998) found some

evidence for an adaptation effect, which means a reoccurrence of stuttering after extended use of FAF. Adaptation effects in fluency enhancing conditions were rarely investigated, but could help to study whether short term mechanisms like distraction are active in the fluency enhancement.

The authors want to make a first step investigating adaptation effects in fluency enhancement. Therefore, the purpose of the presented study is to investigate, whether short term adaptation effects occur in fluency enhancing by delayed and frequency shifted auditory feedback. Furthermore, data concerning sex differences should be provided, since gender effects have been rarely studied.

## METHOD

Participants were 22 volunteers who stutter, 11 women and 11 men (average age: 34.4 years (SD=10.95) respectively 30.5 years (SD=6.16)). The stuttering severity according to Riley (1972) was described as „mild“ for 2 women and 3 men, as „moderate“ for 6 women and 3 men, as „severe“ for 2 women and 4 men and as „very severe“ for 1 woman and 1 man (women: Riley scale = 20, SD=6.54; men: Riley scale = 19.2, SD=7.79). The subjects had to read passages with non altered (NAF), delayed (53 ms) (DAF) and frequency-shifted (-1/2 octave) auditory feedback (FAF). In previous studies using such a delay interval and frequency shift magnitude stuttering, reduction was found. In each feedback condition 5 passages consisting of 200 syllables had to be read, which present 5 moments of measurement defined as T1 to T5.

For manipulating auditory feedback a commercial device was used (DFS 404, Casa Futura Technologies, Boulder, Colorado, USA), that works on a digital basis with a sampling frequency of 32 kHz and a sampling depth of 14 bit. The subjects heard their own speech signal via headphones with open ear pads (porta Pro, Koss, Denver, USA) with the feedback volume tuned in a way that a 75 dB (A) sinusoidal tone at the microphone lead to a feedback volume of 70 dB (A) in the headphones. Subjects perceived the adjusted volume as normal feedback volume. A video camera recorded the experimental sessions.

Stuttering at each single text passage was measured with the Percentage of Discontinuous Speech Time (PDST; Starkweather, 1993). For this purpose the audio signal of the video recording was digitized by a commercial PC with sound card. By using software for sound processing (Sound Forge 4.0, Sonic Foundry, Madison, USA) the speech sample was listened to repeatedly and in the waveform graph the speech disfluencies were marked with the computer mouse, then deleted. All kinds of disfluencies were removed by e.g. all repetitions of a segment prior to the last one, so that the last fluent production of the segment remained. Silent and audible prolongations were cut in a way, that when listening to the speech sample again the respective segment sounded subjectively fluent. By comparing the duration of the resulting quasi-fluent speech sample and the duration of the original speech sample the Percentage of Discontinuous Speech Time was calculated as  $PDST = 100 \cdot (1 - \text{duration of the quasi-fluent speech sample} / \text{duration of the original speech sample})$ . A high interrater reliability in determining the PDST in people who stutter was found in another study (Natke, 2000).

Furthermore, fluent speech rate in syllables per minute was determined under each condition based on the quasi-fluent speech samples, so speech rate was not affected by disfluencies. t-tests for dependent samples were calculated to prove differences in PDST for auditory feedback condition and moment of measurement; sex differences were analyzed according to t-tests for independent samples. p-values without adjustment were reported.

## RESULTS

Figure 1 presents the results of PDST under the different feedback conditions for both groups, averaged over the 5 reading texts. Figure 2 shows the reduction of stuttering comparing male and female subjects in units of PDST.

Under NAF women had a PDST of 17.6 % and men of 27.5 % ( $p=0.275$ ). The PDST varied from 6.1 % to 60.6 % for women and from 5.1 % to 76.6 % for men. For both sexes stuttering was reduced by delayed and also by frequency shifted auditory feedback. Under the DAF condition, stuttering was reduced to 5.1 % for female subjects ( $p=0.006$ ) and to 18.4 % for male subjects ( $p=0.002$ ) (Figure 1). This means a reduction of stuttering of 71.3 % for women (12.6 units PDST) and 33.1 % for men (9.1 units PDST) (Figure 2). Testing sex differences in reduction of stuttering yields  $p=0.513$ . Under the FAF condition stuttering was reduced to 6.3 % for women ( $p=0.010$ ) and to 19.1 % for men ( $p=0.000$ ) (Figure 1). This means a reduction of 64.2 % for women (11.3 units PDST) and of 30.5 % for men (8.4 units PDST) (Figure 2). Testing sex differences in reduction of stuttering yields  $p=0.453$ .

Single subjects reacted heterogeneously, as standard deviations indicate. The reduction of stuttering under DAF ranged from 0.3 % to 85.2 %. For FAF, variability was similar with reductions in a range from 1.4 % to 82.0 %.

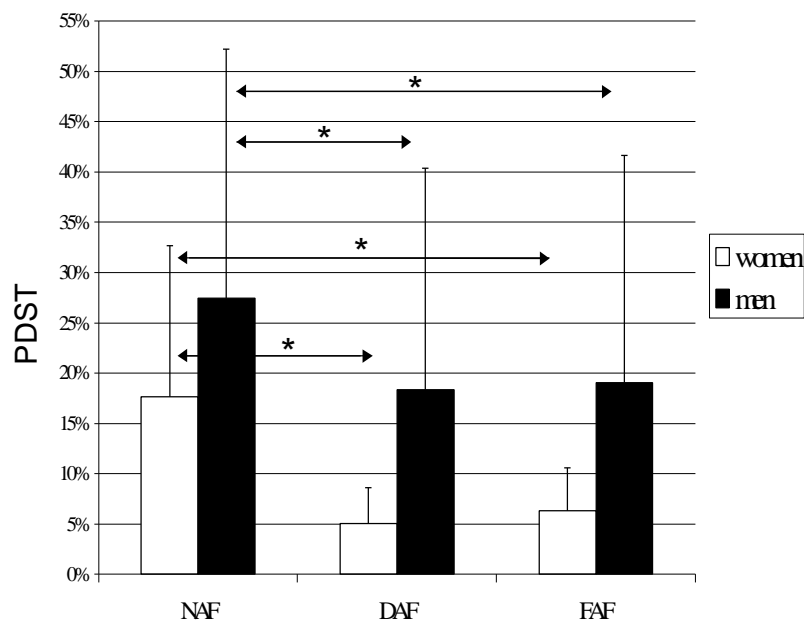


Figure 1: Mean Percentage of Discontinuous Speech Time (PDST) and standard deviations for non altered (NAF), delayed (DAF; delay interval 53 msec) and frequency shifted (FAF; frequency shift: -1/2 octave) auditory feedback conditions for women and men who stutter. \* indicates  $p<.05$  based on two sided t-tests.

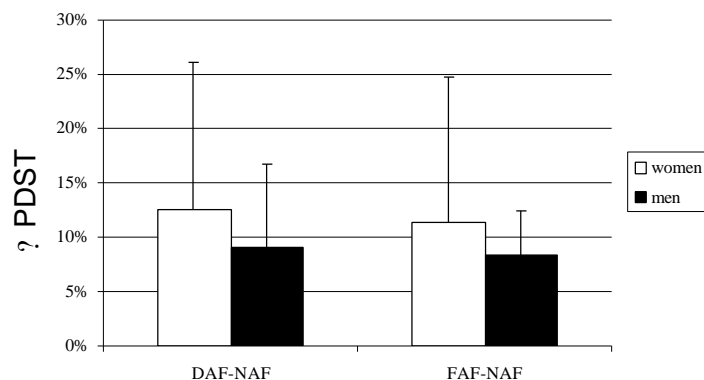


Figure 2: Mean reduction of stuttering in units of Percentage of Discontinuous Speech Time (? PDST) presented as differences between non altered auditory feedback (NAF) and delayed auditory feedback (DAF; delay interval 53 msec) respectively between non altered auditory feedback (NAF) and frequency shifted auditory feedback (FAF; frequency shift: -1/2 octave) (units of PDST) for women and men who stutter.

As shown in Figure 3, both groups show tendencies for small increases in stuttering over a time period from T1 to T5 under delayed as under frequency shifted auditory feedback. For the women the difference in PDST between T1 and T5 was 3.0 % in units PDST (SD=4.9) for DAF (p=0.074) and 2.5 % in units PDST (SD=5.21) for FAF (p=0.142). For the men the difference between T1 and T5 was 7.8 % in units PDST (SD=16.48) for DAF (p=0.146) respectively 2.9 % in units PDST (SD=7.71) for FAF (p=0.171). There is also a difference in PDST under the NAF condition in both groups. The difference between T1 and T5 is 0.7 % in units PDST (SD=7.24) for women (p=0.749) and 3.1 % in units PDST (SD=6.86) for men (p=0.171). Overall, significance is missed in all cases and only for the women a tendency for an increase in PDST under DAF was found. Between T2 and T4 the development is irregular for most of the conditions.

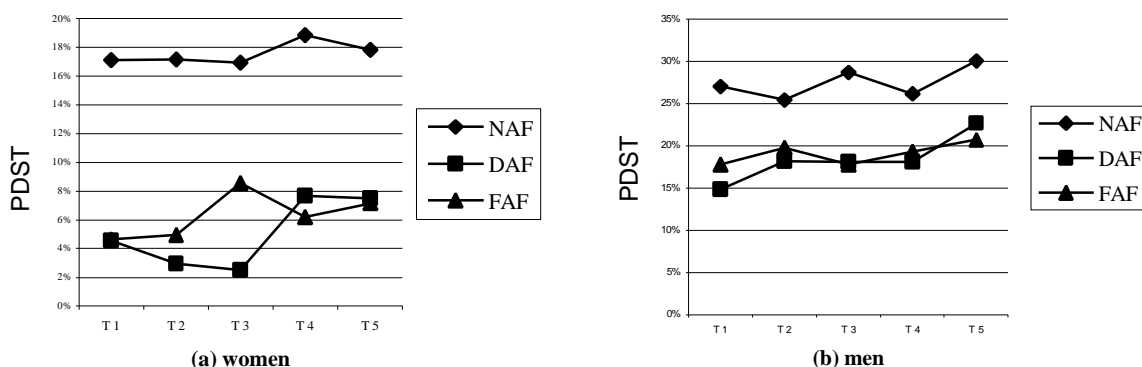


Figure 3: Progress of Percentage of Discontinuous Speech Time (PDST) with growing amount of reading (moments of measurement T1-T5) for non altered (NAF), delayed (DAF; delay interval 53 msec) and frequency shifted (FAF; frequency shift: -1/2 octave) auditory feedback conditions for women (a) and men (b) who stutter.

In Figure 4 fluent speech rate is presented. Male subjects reduced their speech rate from 237.3 syllables per second (spm) under NAF to 216.7 spm under DAF ( $p=0.003$ ), whereas no reduction occurs under FAF (237.2 spm;  $p=0.494$ ) compared to NAF. In female subjects no reduction of speech rate was found with 199.5 spm under NAF, 196.9 spm under DAF ( $p=0.402$ ) and 207.9 spm under FAF ( $p=0.104$ ).

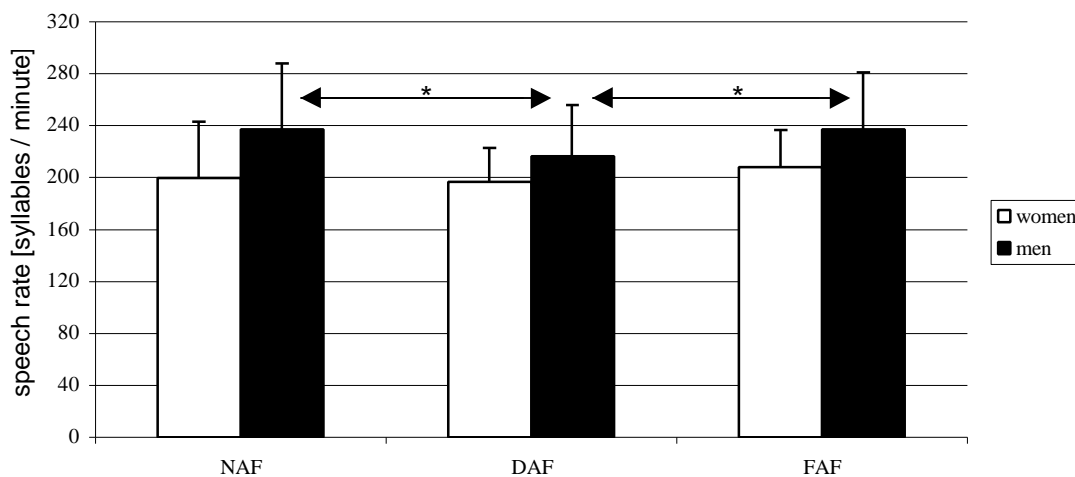


Figure 4: Mean fluent speech rate (syllables / minute) and standard deviations for non altered (NAF), delayed (DAF; delay interval 53 msec) and frequency shifted (FAF; frequency shift: - 1/2 octave) auditory feedback conditions for women and men who stutter. \* indicates  $p < .05$  based on two sided t-tests.

## DISCUSSION

In this study the fluency enhancing effect of delayed and frequency shifted auditory feedback was found. However, interindividual differences, are strong. Men reduced their speech rate under delayed auditory feedback, which is likely due to prolongation. In a study with intermittent delayed auditory feedback (Kalveram, 1984) women showed no prolongation effect compared to men. This may be the reason why no deceleration in women was found. However, regarding fluency enhancement gender differences could not be observed, neither under delayed nor under frequency shifted auditory feedback. It is concluded that prolongation leading to a reduction of speech rate is not necessarily associated with fluency enhancement by DAF and FAF.

No substantial adaptation effects were found. Only under DAF, women showed an increase in stuttering. If this can be considered a gender effect, is questionable. Future work should investigate more prolonged use of modified auditory feedback. If more evidence for adaptation effects is provided, this may imply that a shift of attention operates. However, until now there is no indication for strong short term adaptation effects and for differences between adaptation in fluency enhancement by FAF and DAF, as suggested by the analogy to the masquerade effect (cf. introduction).

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## ABSTRACT

Eleven women and eleven men who stutter had to read five text passages, each with non altered, delayed (53 msec) and frequency shifted (-1/2 octave) auditory feedback, provided by headphones. Stuttering was measured as Percentage of Discontinuous Speech Time, by which durations of all stuttering moments are determined and related to the entire duration of the speech sample. For both sexes stuttering was reduced by delayed and also by frequency shifted auditory feedback. No substantial increases in stuttering over the time within the conditions with modified feedback were found. Furthermore, the results show that male subjects reacted with reduced speech rate under delayed auditory feedback while women did not. Neither group exhibited a reduction in speech rate under frequency shifted auditory feedback. It is concluded that a reduction of speech rate is not necessarily associated with fluency enhancement by DAF and FAF. Future studies should address adaptation effects to provide more information about underlying mechanisms in fluency enhancement.

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