Effectiveness of frequency shifted feedback at reducing disfluency for linguistically easy, and difficult, sections of speech (original audio recordings included)

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Abstract. Frequency shifted feedback (FSF) induces fluency when presented to speakers who stutter. This study examined whether FSF was more effective at removing disfluencies on easy or on difficult sections of speech (where difficulty was defined with respect to utterance and word length). There were more disfluencies on the difficult sections than on the easy sections. There were significantly fewer disfluencies under FSF than in normal listening conditions (indicating that FSF improved fluency). There was no interaction between difficulty of material and type of feedback when disfluency rate was used as the dependent variable, suggesting that targeting FSF on easy sections of speech is as effective as targeting it on difficult sections. The original audio data are provided in this report and can be used by readers to check for themselves the characteristics of voice control that alter when FSF is delivered. **Keywords:** Frequency shifted feedback, stuttering.

1. Introduction

Howell (2004) reviewed the development of prosthetic aids that alleviate stuttering that use delayed auditory (DAF), or frequency shifted (FSF), feedback (Howell, 2004). The now extensive literature on the fluency-enhancing effects of these forms of altered auditory feedback indicates unequivocally that they improve the fluency of people who stutter during the time in which the altered sounds are played. These effects appear to be involuntary. Consequently, it has been suggested that they differ from conscious strategies that speakers who stutter can adopt to improve their fluency such as by changing speech rate (Saltuklaroglu, Dayalu & Kalinowski, 2002).

People who have read reports about the fluency enhancing effects of FSF and DAF a) want to know more about how these altered forms of feedback affect people who stutter, b) those who stutter may wish to try the effects for themselves, and c) speakers who stutter and researchers alike want to know how immediate the effects of an alteration are and whether DAF and FSF vary in their effectiveness on different types of utterance. *Stammering Research* is able to address each of these issues, a) by providing access to audio samples of stuttered speech under FSF in a similar way to the speech produced in normal listening situations described by Howell and Huckvale (2004) (see Appendix A for details how to access data from the current experiment), b) by making trial software widely available that readers can use to produce DAF and FSF effects to try out or to research with (Joukov, 2004), and c) by publishing studies that report on the effectiveness of FSF on different types of material (current article). The effectiveness issue is examined in the current study by varying the difficulty of words and seeing how FSF affects sections of speech that differ in difficulty. This simulates the different levels of difficulty individual speakers experience on utterances.

Knowing the effects of intermittent presentation of FSF is important because continuously presenting such sounds has certain drawbacks. Thus, a) FSF noises are distracting and, because of this, may affect speech control, b) the altered sounds give the listener an extra dose of noise which may cause noise trauma, and c) when prosthetic devices are worn in everyday situations, they may prevent users hearing sounds that alert of danger (such as approaching buses or shouted warnings). In all these cases, it is advisable to limit presentation of FSF (or altered sounds in general). Besides these essentially negative motivations for limiting exposure to FSF, there is one potential positive advantage to intermittent presentation. If FSF is presented intermittently according to prescribed schedules, it may be possible for users of prosthetic feedback devices to be gradually weaned away from using them (Howell, 2004a). This argument is based on the concept of partial reinforcement schedules from the animal learning literature (Reed & Howell, 2001). Partial reinforcement refers to the observation that animals continue to make responses they have learned for longer if the reward for that class of response is presented intermittently (see Reed and Howell, 2001 for a discussion of partial reinforcement in relation to the effects of FSF). Thus if FSF acts as a way of eliciting a response (leads to fluent speech here), and if the FSF is presented only on a proportion of episodes on which speakers experience disfluency, according to the partial reinforcement findings the fluency that results may be maintained for longer. Since this reduces disfluency rate, subsequently the FSF would need to be presented less often to achieve the same level of partial reinforcement and enhancement in fluency. This process would operate continuously requiring less and less FSF-presentation. In this way, it might ultimately be possible to discard use of FSF altogether. There is little evidence in the literature about what happens when altered feedback is presented intermittently, but what there is suggests that the alterations are effective at eliciting fluent responses (as required in the above account) even when exposure is limited. Thus, Howell, El-Yaniv and Powell (1987) investigated presenting FSF just at syllable onset or through the entire syllable. They found that presenting FSF at onset alone was as effective as presenting the sound throughout the syllable. Howell (2004) also discussed the Hector aid that produced a buzz as feedback when speech rate was too high. Informal reports suggest that this was effective at maintaining fluency. The fact that there is selective feedback (the buzz occurs only when speech rate is too high) makes Hector another form of intermittent feedback.

To summarize, more needs to be known about the effects of limiting exposure to FSF and its effectiveness in affecting fluency in these circumstances. In the current study, sections of speech that were linguistically easy or difficult and the effects of presenting intermittent feedback on sections at specific levels of difficulty were established. Difficulty was varied by increasing sentence length (Logan & Conture, 1995; Silverman & Bernstein Ratner, 1997; Yaruss, 1999) and duration of words (Brown, 1945) in the difficult text relative to the easy text. FSF was presented on the easy or difficult sections according to a prescribed schedule. The intention was to see whether switching FSF on while the speaker produced an easy section of speech was as effective as switching FSF on while producing a difficult section of speech where effectiveness was specified in terms of reduced time to read a section and/or a reduction in number of disfluencies on that section.

Method

Participants

Fourteen children who stutter took part in the study. Their ages ranged from 9 to 18 years, with a mean age of 14.52 years. There were 11 males and 3 females and individual details (gender and age) are given in Table 1.

Table 1. Details of participants

ID	Gender	Age
0075	Female	16y 10m
0097	Male	18y 2m
0100	Male	17y 0m
0104	Male	16y 4m
0119	Male	15y 7m
0123	Male	15y 0m
0127	Male	13y 9m
0392	Male	9y 2m
0395	Female	13y 4m
0818	Female	14y 11m
0876	Male	14y 9m
0880	Male	15y 3m
0990	Male	10y 10m
1017	Male	12y 5m

Materials and procedure

There were two experimental texts (these are given in Appendix B). The experimental texts included four test sections each of approximately 50 words. In each text, two of the sections were difficult and the other two were easy. The difficult sections had long sentences (Logan & Conture, 1995; Silverman & Bernstein Ratner, 1997; Yaruss, 1999) and long words (Brown, 1945) compared to the easy sections. The difficulty of the specified sections was checked statistically by independent t test (the four easy sections were compared with the four difficult sections). The difficult sections had significantly longer sentences ($t(6) = 3.175$, $p = .019$) and words ($t(6) = 4.859$, $p = .003$) than the easy sections. The number of content and function words and words starting with consonants and vowels (Brown, 1945) were also checked to ensure that they did not differ significantly in incidence between easy and difficult sections in the two texts (in neither case were these significant). Thus, of the factors examined, only sentence and word length differed between easy and difficult sections (and these were both longer in the difficult sections).

In each text, there was a point where an easy section changed to a difficult section and another point where a difficult section changed to an easy section (the order in which easy-difficult or difficult-easy appeared was counterbalanced between the two texts). The experimenter switched FSF on or off at these transition points as prescribed in the design. The coextensive difficult plus easy and easy plus difficult sections were separated by a buffer zone approximately 20 words in length which was always presented under normal listening conditions (not included in the analyses) and each text also started and ended with another buffer of about 20 words (also spoken under normal listening conditions). Each text was read twice by each participant and across readings the sections on which FSF occurred were reversed across the two readings. With the counterbalancing, participants read each easy and difficult section in the two texts, under two feedback conditions (normal listening and FSF) (i.e. a 2 levels of difficulty x 2 texts x 2 feedback presentation condition design). The counterbalancing also minimized the chance of adaptation and fatigue effects affecting the results.

Feedback conditions and recordings

The participant sat in a sound-treated cubicle. FSF was produced by a Digitech S400 effects processor set to produce a half octave shift down in frequency. The input to the Digitech was by a Sennheiser condenser microphone and the altered sound was replayed over Sennheiser HD250 linear 2 headphones. Speech output was also relayed to a loudspeaker outside the sound-treated cubicle which the experimenter used to monitor the speech to determine when to switch between normal and FSF listening conditions. Speech was recorded onto computer using a second Sennheiser condenser microphone at the same time as the participant read the texts.

Analysis

The time taken to read each 50 word section was measured using Cooledit software. Speech was replayed to locate the disfluencies in each 50 word section using this same software package. Disfluencies that were counted included segment, part-word and word repetitions, segmental and syllabic prolongations, extraneous sequences (mostly glottalic sounds involving stricture in the glottis) excessive aspiration and pauses longer than 100 ms. The accuracy of the transcriber was assessed previously against a second trained transcriber on eight similar recordings to those collected here to estimate inter-judge reliability. 96% agreement on inter-judge fluency judgment was obtained on all words giving a kappa coefficient of .92 which is higher than chance (Fleiss, 1971).

Results

The mean times to read the easy and difficult sections under normal listening (NAF) and FSF are given in Table 2 separately for each of the texts.

Table 2: Reading time statistics for each text (in column 1, 1 is the Kate text and 2 is the Alice text presented in Appendix B) for the easy and difficult 50-word sections within a text (indicated in column 2) when spoken under normal (NAF) or FSF listening conditions (column three). Mean times (in seconds) are given in column four and standard deviations in column five.

Text Used	***Passage Difficulty***	***Feedback Used***	***Mean Time (seconds)***	***Standard Deviation (seconds)***
1	Difficult	NAF	32.11	21.04
1	Difficult	FSF	25.86	11.57
1	Easy	NAF	23.36	19.14
1	Easy	FSF	19.21	5.76
2	Difficult	NAF	30.14	21.13
2	Difficult	FSF	30.10	29.21
2	Easy	NAF	24.96	15.53
2	Easy	FSF	19.11	6.37

Inspection of Table 2 shows that for both the texts, the mean times taken to read difficult sections are greater than the mean times taken to read easy sections. It also appears that the mean times taken to read sections under FSF are less than the mean times taken to read sections under NAF. These impressions were examined statistically using a repeated measures analysis of variance (ANOVA) with factors text (two levels – Kate and Alice), difficulty (two levels – easy, difficult) and feedback condition (FSF or normal listening). There was no significant main effect or interaction with the text factor, which shows that overall the two texts led to similar performance. The effect of difficulty of text section was significant ($F1,27 = 15.11$, $p = .001$) supporting the impression that easy sections were read quicker than difficult sections. There were no significant effects of feedback type (main effect or interaction), which suggests that FSF did not significantly reduce the time taken to read the easy or difficult sections relative to normal listening.

The next question examined was whether FSF and text difficulty affected disfluency rate. The data are presented in Table 3 in the same way as with the timing data (Table 2), except this time mean number of disfluencies and the associated standard deviations are given in columns four and five.

Table 3. Disfluency statistics for each text (in column 1, 1 is the Kate text and 2 is the Alice text presented in Appendix B) for the easy and difficult 50-word sections within a text (indicated in column 2) when spoken under normal (NAF) or FSF listening conditions (column three). Mean number of disfluencies are given in column four and standard deviation in column five.

Text Used	***Passage Difficulty***	***Feedback Used***	***Mean Number of Disfluencies***	***Standard Deviation***
1	Difficult	NAF	5.61	4.28
1	Difficult	FSF	3.82	3.73
1	Easy	NAF	3.37	3.50
1	Easy	FSF	1.71	1.47
2	Difficult	NAF	4.24	4.19
2	Difficult	FSF	3.34	2.90

2	Easy	NAF	3.39	2.76
2	Easy	FSF	2.95	3.04

It appears from Table 3 that more disfluencies were made on difficult sections than on easy ones and that there were more disfluencies under normal listening than under FSF. A similar 2x2x2 repeated-measures ANOVA was carried out on the data as was conducted on the timing data. There was a significant effect of difficulty of a section ($F1,27 = 15.02$, $p = .001$) which showed that there were more disfluencies on the difficult sections. There was also a significant main effect of feedback ($F1, 27 = 4.15$, $p = .05$) that showed FSF reduced the number of disfluencies relative to normal listening. There were no interactions, nor any effect of text type.

Discussion

Linguistically difficult sections led to increased reading time and disfluency rate relative to linguistically easy sections. FSF did not have any effect on reading time in this study, but did reduce number of disfluencies relative to normal listening. Some reduction in reading time under FSF would have been expected from the literature (Howell, 2004) and corresponding sections produced under normal listening and FSF all showed reduced reading time under FSF (Table 2). It is not apparent why no statistical effect was found here though it is possible that other ways of varying difficulty (e.g. using a high proportion of content words or material with high levels of phonological difficulty) might have had more impact. Alternatively, more fine-grained timing analyses might reveal differences between normal listening and FSF. To this end, the data are available for anyone to examine these or other hypotheses (Appendix A). The decrease in disfluency rate under FSF is consistent with what has been reported previously in the literature (e.g. Howell et al., 1987).

The lack of any interaction between task difficulty and feedback condition (either when time to read the passage or number of disfluencies were examined) indicates that FSF is equally effective on easy and on difficult material: Switching FSF on decreased disfluency rate by the same amount as the increase that occurred when FSF was switched off, there was no differential change depending on linguistic difficulty. The restitution of baseline disfluency rates when FSF was switched off is also apparent if the recordings of the data used in these analyses are listened to (Appendix A – while listening to these recordings, Saltuklaroglu et al.'s 2002 claim that these effects are involuntary can also be checked). Thus FSF has an intermittent effect in controlling disfluency rate making it suitable for use as a fluent response elicitor that can be used for partially reinforcing and, potentially, establishing long term effects of fluency, with FSF (Reed & Howell, 2002). This possibility remains to be investigated.

Terms and copyright conditions for the use of the audio data (See Appendix A for access information).

The data and software are freely available to anyone for research and teaching purposes. If the data and/or software are used in publications, theses etc., users have to a) notify Howell (p.howell@ucl.ac.uk), b) acknowledge the source in any publication by referencing this article, c) include an acknowledgement that data collection was supported by the Wellcome Trust.

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Appendix A – Data description

This Appendix contains an indication where UCL's archive of recordings of speakers who stutter speaking under FSF are located and how they can be accessed.

There are 14 speakers and four recording per speaker making 56 files in all. Recording are in SFS format (see Howell & Huckvale, 2004 for a description). The four recordings for a speaker were for the two texts (Kate and Alice) and two readings of each text. Filenames start with a four figure code that identifies the speaker (e.g. 0075), followed by underscore, recording number (r1-r4), underscore, text (1=Kate, 2=Alice), underscore and four letters representing feedback sequence on the 50-word sections (n=normal listening, f=FSF

The 56 SFS speech files can be accessed and downloaded from:

http://speech1.psychol.ucl.ac.uk/feedbackdata.htm

Appendix B – Texts used in the experiment

Kate

Kate witnessed the robbery of a woman's handbag. The police were called and had arrived to ask her some questions.

(Difficult) Mrs Mcalpine please could you give us a clear and accurate description of the thief including any unusual distinguishing characteristics. Please be careful not to omit any critical details as these are probably the most important features that will help us to track down and arrest and hopefully prosecute him.

(Easy) Of course. he was a young man. probably aged between fifteen and twenty. He was wearing a blue tracksuit. He had brown hair and was wearing a cap. The cap was also blue. He was about six foot tall and he was wearing yellow trainers with blue stripes on them.

The policeman carefully wrote down the information Katie had given him and then looked up to ask her another question.

(Difficult) Could you describe exactly what you witnessed. Again be extremely careful to mention every single detail however small. We need detailed information about exactly what happened so that we can determine what to do next. Your witness account is very important to our investigation so be as accurate as possible.

(Easy) I had just bought a cup of tea. an old lady was in the queue behind me. She ordered a drink. I went to sit down. The lady opened her bag to get her purse. All of a sudden the young man behind her snatched her bag and ran off.

Kate answered more questions before the police moved on to the next witness. She hoped they would catch the thief.

Alice

The following conversation is between Alice and her teacher, Mrs Jones. They are talking about what they did at Easter.

(Easy) I went to the fair. And then I played with my friend. We got some candy floss and some toffee apples. They were nice and sweet. And then we went on the ferris wheel for ages. It was so fun. It was the best fair I have ever been to.

(Difficult) That sounds particularly enjoyable Alice. I'm sure you had a wonderful time especially as it was your birthday. Were you given many exciting presents by your family and friends? Did any other unusual or surprising things happen or do you remember anything else that you want to tell me about?

Alice wrinkled her forehead as she tried to remember the best parts of her birthday. Then she nodded, and said:

(Easy) Yes. I got lots of great presents. My mum gave me a hamster. He is so cute and soft. I called him Andy. I also got a ball that he can run around the house in. He looks funny when he does that. And my dad gave me a kite.

(Difficult) That's terrific. I adored my pet hamster when I was about thirteen. My favourite game was to hide hundreds of tiny pieces of his food all around my bedroom and then allow him to scurry about and discover where they all were before he gobbled them all up incredibly quickly.

They both laughed. It seemed they had lots in common, even though Mrs Jones was a teacher and Alice