# Relationships between Auditory Processing and Fluency in Adults who Stutter

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## Introduction

- Dysfunction within the auditory system has been hypothesized as an underlying mechanism for stuttered speech for over 50 years.
- There are two main observations that have led to this speculation:
  - Stuttering symptoms are significantly reduced for many speakers who stutter when they talk under delayed auditory feedback,
  - Auditory monitoring is an integral component of accurate, fluent speech production in typical speakers.

- To date, researchers have examined auditory functioning in speakers who stutter from a variety of perspectives, including peripheral auditory acuity , brainstem evoked responses, and central auditory processing. Examples:
  - Stromsta (1972) reported atypical phase responses among people who stutter on a pure-tone cancellation task; however, subsequent research by others failed to replicate the finding.
  - Hall and Jerger (1978) reported that adults who stutter performed worse than nonstutterers on acoustic reflex amplitude functions, synthetic sentence identification with ipsilateral competing message (SSI-ICM), and the staggered spondaic word test (SSW). They noted that these differences were subtle, but worthy of further investigation.
  - Foundas et al. (2004) reported evidence of atypical auditory processing during a dichotic listening task for left-handed men and right-handed women who stutter (but not for right-handed men who stutter), suggesting that atypical auditory functioning may reflect atypical hemispheric dominance or be symptomatic of compensatory neural mechanisms.
- To date, there is relatively little information regarding:
  - The performance of people who stutter during contemporary auditory processing tests, particularly those that emphasize the time domain.
  - There is also relatively little information on the relationship between a speaker's auditory system functioning and the severity with which he or she stutters, with and without the presence of altered auditory feedback.
- The present study was conducted as a preliminary investigation of these issues.

## Method

### Participants

- 11 adults who stutter (2 females, 9 males); Severity ratings: 2 very mild, 3 mild, 4 moderate, 2 severe.
- *M* age = 20.5 years; *SD* = 3.88 years.
- All reported having stuttered since childhood.
- None were enrolled in fluency therapy at the time of data collection. All were in college or college graduates.

### Data Collection and Analysis

- Data were collected during three 75-minute sessions, scheduled over a 3-week period.
- **Speech samples** were elicited during sessions 1 and 3 using a standard conversation task (~300 syllables) and tasks from the *Stuttering Severity Instrument-4* (Riley, 2009).
  - In session 3, speech samples were obtained with and without altered auditory feedback (AAF). In session 1, samples were elicited only under normal auditory feedback (NAF).
  - AAF was introduced via the SpeechEasy® device (Comfort Fit Model; Janus Development Group, Inc.), which provided both delayed auditory feedback (60 ms delay) and frequency altered feedback (+500 Hz). Participants' initial response to AAF (i.e. , fluency within first 30 min of use) was assessed.
- **Tests of Auditory Function:** administered in session 2.
  - Basic audiometric data (otoscopy, pure-tone air and bone conduction thresholds, speech recognition thresholds, word recognition at MCL, tympanometry, and acoustic reflex thresholds) were gathered for each participant.
  - Auditory processing tests: All tests were delivered from CD recordings to ER-3A insert earphones via a calibrated audiometer (GSI 61).

1. The SCAN-A (Keith, 1994) is designed to identify auditory processing disorders in adolescents and adults. Subtests: Filtered Words, Auditory Figure-Ground, Competing Words, and Competing Sentences. The four listening tasks demand successful brainstem and cortical processing of speech signals. Test items were presented at 50 dB HL.
2. The Gaps in Noise Test (Musiek, 2005) is designed to assess auditory temporal resolution. Listeners attempt to detect randomly presented gaps (2 to 20 ms in length) in broad band noise stimuli.
3. Dichotic Digits (triple pairs; Kimura, 1961) is a tool for assessing binaural processing/separation. The triple pairs version helps avoid ceiling effects observed with the single and double pair versions of this test. The dichotic digits were delivered at 50 dB HL in a non-directed mode.

## Results

### Baseline Stuttering Measures

- Mean stuttering frequency during conversational speech with NAF was stable between session 1 and session 3 ($t(10) = -0.20$, $p = .84$).
- Mean SSI-4 scores were also stable between the two sessions ($t(10) = .00$, $p = 1.00$).

Table 1. *Fluency-related performance, under NAF, across sessions.*

| | Performance Measure | | | |
|---|---|---|---|---|
| | % Syllables Stuttered | | SSI-4 Score | |
| Session | *M* | *SD* | *M* | *SD* |
| 1 | 13.38 | 9.86 | 25.64 | 25.64 |
| 3 | 11.90 | 8.18 | 6.52 | 7.16 |

### Effects of AAF on Stuttering

- AAF data were available for 10 of the 11 participants. Mean stuttering frequency in conversation was significantly lower during the AAF condition than in the NAF condition ($t(9) = 4.02$, $p = .003$, $d = .50$). See Figure 1.
- The mean SSI-IV Score was significantly lower during the AAF condition than it was in the NAF condition ($t(9) = 8.27$, $p < .001$, $d = .25$). See Figure 2.

*Figure 1.* Mean stuttering frequency (+/- 1SD) during conversation in NAF and AAF conditions.

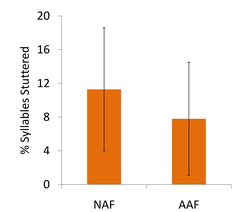
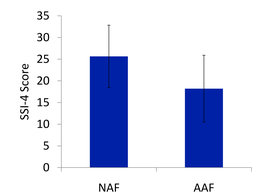



*Figure 2.* Mean SSI-4 scores (+/- 1 SD) in NAF and AAF conditions.




- In the AAF Condition: 9/10 participants had fewer stuttered syllables and 10/10 participants had better SSI-4 scores.

### Basic Audiometric Data

- All participants presented normal pure tone thresholds, word recognition scores, tympanometry profiles, and acoustic reflex thresholds.

### Dichotic Digits (Triple Pairs)

- Pairs of digits were presented simultaneously to right and left ears in single and dual task conditions (3 digit pairs (6 total) per set). The percent of digits recalled per ear was computed .

| | Test Condition | | | |
|---|---|---|---|---|
| | Single Task | | Dual Task | |
| Group | RE | LE | RE | LE |
| Test Norm | 91 (9) | 85 (12) | 85 (12) | 78 (12) |
| Participants | 97 (6) | 94 (7) | 87 (15) | 82 (11) |

Table 2. *Mean (SD) Percent of Digits Recalled*

Participants who stutter performed within normal limits in all conditions.

### SCAN-A

Overall, 36% of the participants scored more than 1 *SD* below the mean on the *Competing Sentences* subtest, and 27% did so on *Competing Words*. Further, 2 of 11 participants (18%) had overall mean scores that fell more than 2 SDs below the mean.

Table 3. *Group and individual results from the SCAN-A test.*

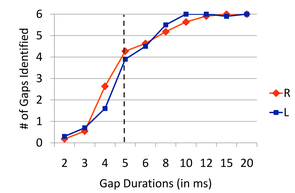
| | Percentile Rank | | |
|---|---|---|---|
| Subtest | Mean | SEM | # of participants with CI < -1 SD |
| Filtered Words | 52.09 | 6.43 | 1 |
| Aud. Figure-Ground | 46.18 | 7.73 | 1 |
| Competing Words | 22.36 | 7.72 | 3 |
| Competing Sentences | 35.18 | 8.58 | 4 |
| Overall | 26.18 | 5.48 | 2 |

Interestingly, *all* errors on the *Competing Sentences test* were associated with left ear stimulus presentation.

### Gaps in Noise (GIN) Test

- Participants listened to 6 s stretches of noise that contained 0 to 4 silent gaps. Gap duration ranged from 2 ms to 20 ms. Participants recorded gaps via button press. Threshold = shortest gap duration with 4/6 (67%) correct identifications.

*Figure 3 (below).* Mean number of gaps detected at 10 gap durations. The threshold for typical adults is 5 ms (see dashed line in figure). Group data suggested participants performed within normal limits in right (R) and left (L) ears.




| | Ear | |
|---|---|---|
| Participant | R | L |
| 1 | 4 | 5 |
| 2 | 5 | 8 |
| 3 | 5 | -- |
| 4 | 5 | 8 |
| 5 | 5 | 5 |
| 6 | 5 | 8 |
| 7 | 8 | 8 |
| 8 | 4 | 4 |
| 9 | 6 | 6 |
| 10 | 4 | 4 |
| 11 | 6 | 5 |
| *M* | 5.18 | 6.10 |
| *SD* | 1.17 | 1.73 |

Table 4. *(left). Individual data for gap detection in right (R) and left (L) ears. Note. Orange cells = response is above threshold.*

For the right ear, responses for 3 of 11 participants were above threshold. For the left ear, responses for 5 of 10 participants were above threshold.

Table 5. *Relationships between amount of reduction in stuttering frequency under AAF and above –threshold responses on the GIN Test*

| | | Typical GIN Threshold? | | |
|---|---|---|---|---|
| % fluency improvement with AAF | Participant | RE | LE | SSI-4 Rating |
| 122 | 2 | yes | no | mild |
| 111 | 8 | yes | yes | mild |
| 100 | 11 | no | yes | very mild |
| 93 | 10 | yes | yes | moderate |
| 63 | 4 | yes | no | moderate |
| 50 | 5 | yes | yes | very mild |
| 47 | 7 | no | no | severe |
| 38 | 6 | yes | no | moderate |
| -8 | 9 | no | No | severe |

- Data in Table 5 are for the 9 participants who completed both the AAF condition and the audiometric assessment.
- 6 of the 9 participants had atypical thresholds in at least one ear (orange cells). Note that 4 of these 6 individuals had moderate or severe stuttering and exhibited either relatively modest or no improvement under AAF.
- Both participants with severe stuttering exhibited atypical thresholds binaurally.
- P11 failed both the SCAN-A and GIN, but still showed AAF benefit.

## Discussion

- The present findings regarding the effect of AAF on fluency enhancement with people who stutter are generally consistent with past studies (e.g., Armson, et al., 2006).
- The participants who stutter performed within normal limits on the basic audiometric assessment and the dichotic digits (triple pairs) task. The latter task features relatively simple linguistic demands. A subgroup of participants had difficulty on the SCAN-A test, including two with overall scores < 2nd %tile. Difficulty was most often noted on competing message tasks.
- On the GIN test, a non-linguistic task, inspection of individual data showed that 27% of participants had atypical gap detection thresholds in the right ear, and 50% had atypical gap detection thresholds in the left ear. This suggests the presence of a subgroup that has difficulty with tasks requiring relatively fine temporal analysis of auditory information. Two participants, both with severe stuttering, showed this deficit binaurally, suggesting that stuttering severity may be associated with gap detection. Given the small sample and descriptive analysis for GIN data, our interpretation should be considered preliminary.
- The relationship between stuttering and gap detection is not clear. Interestingly, participants with atypical GIN thresholds (particularly in the left ear) tended to show only modest initial benefit from AAF.

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