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ARTICLES

Immediate Effect of Altered Auditory Feedback for Stuttering Treatment: A Systematic Review and Meta Analysis

Efeito imediato do feedback auditivo alterado para o tratamento da gagueira: uma revisão sistemática e meta-análise

Efecto inmediato de la retroalimentación auditiva alterada para el tratamiento de la tartamudez: una revisión sistemática y un metanálisis

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Abstract

Introduction: Fluency disorders may be treated with Altered Auditory Feedback (AAF), although the short-term impact is still uncertain. **Objective:** The objective of this study was to systematically review and evaluate the short-term effect of AAF for the treatment of developmental stuttering in adults and children. **Methods:** This systematic review and meta-analysis involved searches in MEDLINE, Embase, CENTRAL, LILACS, clinical trial registries, and gray literature, with a publication year filter starting from 2000. The risk of bias was evaluated using the ROBINS-I tool, and a meta-analysis was conducted to assess the immediate effect on disfluency frequency. **Results:** There was a reduction in the frequency of disfluencies after the use of AAF. The severity of the disorder and age influence the effect, being more effective in adults and in moderate cases. The combination of delayed auditory feedback +

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Authors' contributions:
GB: conception and planning of the project; data collection and data anlysis; text organization.
MET data collection and data analysis; organization and critical revision of the study.
GBS: organization and critical revision of the study.
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frequency altered feedback (DAF+FAF) seems to induce a greater effect. No evidence of publication bias was found. **Conclusion:** AAF demonstrated positive short-term effects. Furthermore, the use of AAF modification in young people (approximately between 9 and 13 years of age) should not be considered the first treatment option, since these individuals generally do not respond as effectively as adults.

Keywords: Stuttering; Childhood-Onset Fluency Disorder; Speech Therapy; Feedback; Systematic Review; Meta-analysis.

Resumo

Introdução: Os distúrbios da fluência da fala podem ser tratados com Feedback Auditivo Alterado (FAA), embora o impacto a curto prazo ainda seja incerto. **Objetivo:** O objetivo deste estudo foi revisar e avaliar sistematicamente o efeito de curto prazo do FAA para o tratamento da gagueira do desenvolvimento em adultos e crianças. **Métodos:** Esta revisão sistemática e meta-análise envolveu buscas no MEDLINE, Embase, CENTRAL, LILACS, registros de ensaios clínicos e literatura cinzenta, com filtro de ano de publicação a partir de 2000. O risco de viés foi avaliado usando a ferramenta ROBINS-I, e uma meta-análise foi conduzida para avaliar o efeito imediato na frequência das disfluências. **Resultados:** Houve redução na frequência de disfluências após o uso do FAA. A gravidade do distúrbio e a idade influenciam o efeito, sendo mais eficaz em adultos e em casos moderados. A combinação de feedback auditivo retardado + feedback alterado de frequência (FAR+FFA) parece induzir um efeito maior. Nenhuma evidência de viés de publicação foi encontrada. **Conclusão:** FAA demonstrou efeitos positivos de curto prazo. Além disso, o uso da modificação do feedback auditivo em jovens (aproximadamente entre 9 e 13 anos de idade) não deve ser considerado como a primeira opção de tratamento, uma vez que esses indivíduos geralmente não respondem de uma forma tão eficaz quanto os adultos.

Palavras-chave: Gagueira; Transtorno da Fluência com Início na Infância; Fonoterapia; Retroalimentação; Revisão Sistemática; Metanálise.

Resumen

Introducción: Los trastornos de la fluidez del habla puede ser tratados con Retroalimentación Auditiva Alterada (RAA), aunque el impacto a corto plazo aún es incierto. **Objetivo:** El objetivo de este estudio fue revisar y evaluar sistemáticamente el efecto a corto plazo de la RAA para el tratamiento de la tartamudez de desarrollo en adultos y niños. **Métodos:** Esta revisión sistemática y metaanálisis incluyó búsquedas en MEDLINE, Embase, CENTRAL, LILACS, registros de ensayos clínicos y literatura gris, con un filtro por año de publicación a partir del año 2000. Se evaluó el riesgo de sesgo mediante la herramienta ROBINS-I y se realizó un metaanálisis para evaluar el efecto inmediato en la frecuencia de disfluencia. **Resultados:** Se observó una reducción en la frecuencia de disfluencia tras el uso de RAA. La gravedad del trastorno y la edad influyen en el efecto, siendo más eficaz en adultos y en casos moderados. La combinación de retroalimentación auditiva retardada + retroalimentación de frecuencia alterada (RAR+RFA) parece inducir un mayor efecto. No se encontró evidencia de sesgo de publicación. **Conclusión:** La RAA demostró efectos positivos a corto plazo. Además, el uso de la modificación de la retroalimentación auditiva en jóvenes (aproximadamente entre 9 y 13 años) no debe considerarse la primera opción de tratamiento, ya que estos individuos generalmente no responden con la misma eficacia que los adultos.

Palabras clave: Tartamudeo; Trastorno de Fluidez de Inicio en la Infancia; Logopedia; Retroalimentación; Revisión Sistemática; Metaanálisis.

Introduction

Developmental stuttering is a speech fluency disorder characterized by frequent and involuntary repetition, prolongation, or pauses of sounds, syllables, or words, which may be associated with involuntary movements of the face and other parts of the body, according to the International Classification of Diseases 11 (ICD 11)[1]. It frequently results in significant impairment in social communication, personal, family, social, educational, occupational or other important areas of functioning[1]. The incidence of stuttering is approximately 8%[2]. It is known that most children will spontaneously recover from stuttering without specific intervention. The rate of spontaneous recovery is as high as 91%[2].

Studies have associated developmental stuttering with differences in brain anatomy, functioning, and dopamine regulation thought to be due to genetic causes[3]. More specifically, it seems to be associated to dopamine surplus in the striatum causing dysfunction of cortical speech areas[4]. Pharmacologic treatment has received attention in recent years, but so far, there is no pharmacological treatment approved for this condition, and speech and language therapy the indicated treatment[4].

Speech and language pathologists (SLPs) need to assess speech fluency prior to the treatment. For that, the percentage of stuttered syllables or words in a speech task (oral reading, monologue, conversation, telephone conversation) is commonly used. The setting of the assessment can be within the clinic or in daily living situations (DLS). Natural speech may be assessed using a specific instrument that has a scale of 1 to 9, where 1 is "very natural" and 9 is "very unnatural"[5]. This scale is presented without a formal definition of what speech naturalness is, and may be used by different raters, for instance, SLPs, stutterers and fluent people without training in the area (sometimes called lay listeners)[6].

Speech therapy for stuttering may differ between infants and adults, but in general, they can involve identifying and modifying environmental stressors, education for parents and others, and teaching new speech patterns (for instance, controlling and slowing the rate of speech)[7]. With the advancement of technologies, devices have been created and studied with the aim of optimizing speech fluency for people who stutter (PWS). These devices usually employ different types of Altered Auditory Feedback (AAF), that are conditions in which the speaker's own speech signal is picked up by electronic equipment, altered, and then presented back to the speaker. As a result, the speaker hears their own voice sounding slightly different. There are three types of altered auditory feedback used in the treatment of stuttering: masking auditory feedback (MAF), delayed auditory feedback (DAF), and frequency altered feedback (FAF)[8].

MAF is a technique used to influence a person's auditory perception while they speak. It involves masking the sound of the speaker's own voice with noise or external sound, altering how the person hears their own voice, which can impact their speech[8-11]. DAF is another technique that involves the speaker hearing their own voice with a slight delay, usually through headphones. This delay, typically a few milliseconds, can cause changes in speech, such as the prolongation of words and repetition of syllables[8]. FAF is a technique in which the frequency of the speaker's own voice is modified as they speak. This alteration can be perceived as a lengthening or shortening of sounds, occurring within a fraction of an octave relative to the user's fundamental voice frequency[12].

AAF appears to help people become more aware of their speech patterns, resulting in a reduction of stuttering. Research on the immediate effect of AAF adaptation has evaluated oral reading with different delay and frequency settings, and different speech rate[13-15]. Studies are gradually seeking to understand the size of the effect in daily life situations and in telephone conversations[16-18]. DAF and FAF have been shown to reduce the frequency of stuttering in some patients. Recent studies suggest that AAF may improve speech control in the short term, but the long-term effects and effectiveness of AAF vary among individuals[19-20].

Several studies have already conducted literature reviews on therapeutic interventions for stuttering. The most recent review focuses on a systematic analysis of a wide range of interventions for the treatment of stuttering across different age groups, without being restricted to a single method or technique, with the aim of providing a basis for clinical guidelines[21]. A review published in 2011 specifically addresses the effectiveness of DAF in reducing stuttering[22]. The earliest review focuses on the use of AAF in the treatment of stuttering, reviewing studies with a 10-year time period filter[8].

Although this review[8] explored the benefits of AAF, it was published almost 20 years ago.

Thus, we aimed to conduct a systematic review and assessment of the short-term impact of AAF (specifically DAF and FAF, as these are the most commonly utilized technologies) in treating developmental stuttering in both adults and children. Our study focuses on the outcomes related to the frequency of disfluency and the naturalness of speech.

Method

Systematic Review

This systematic review was conducted as recommended by the Cochrane Collaboration and reported according to PRISMA. The study protocol was registered in PROSPERO under identification CRD42020161022.

The inclusion criteria used in this study were: studies involving individuals of any age with persistent developmental stuttering; studies that utilized DAF, FAF, or a combination of the two; studies without comparison or with a control group; studies with primary outcomes measuring changes in the frequency of disfluency and the naturalness of speech; studies that present data from evaluations with and without AAF; and studies with pre- and post-intervention designs, case studies, case series, and Randomized Clinical Trials (RCTs).

The exclusion criteria were: studies with samples of fluent subjects, subjects with neurological stuttering or subjects with psychiatric illness (reason 1); studies that used only MAF or no intervention (reason 2); studies that evaluated the effect at a time other than immediately after the adaptation (reason 3); Studies that did not assess the outcomes of interest to this review (reason 4); studies for which it was not possible to access the abstract or the full text (reason 5).

Searches were conducted across several databases to ensure comprehensive coverage. The database included were the Cochrane Central Register of Controlled Trials, EMBASE, MEDLINE, and LILACS. To capture relevant unpublished studies we also searched on, ClinicalTrials.gov and the WHO International Clinical Trials Registry Platform. Additionally, gray literature was explored through OpenGrey and REHABDATA, providing a broader perspective on the available evidence. The complete search strategies for all databases are available in Appendix 1.

Citations identified in the searches were imported into EndNoteWeb and duplicates were removed automatically and manually. Two independent researchers (GB and MET) evaluated all articles based on their titles and abstracts. Disagreements were solved through discussion between the two researchers, and if agreement could not be reached, a third researcher (BCB) was consulted. The same researchers applied the same method for selection based on the full text. The research team included people fluent in Portuguese, English, and Spanish; the potential eligibility of articles in other languages was initially assessed using Google Translator and, when necessary, the possibility of assistance from someone fluent in the language in question was considered.

A standard protocol for data extraction was developed and tested on ten randomly selected articles included in the study. After adjustments were made to the protocol, one reviewer (GB) performed the initial data extraction for all included articles, and a second reviewer (MET) verified all data. In cases where additional information of papers was needed, the corresponding authors were contacted via email by the primary researcher (GB).

Data were collected regarding identification of the article (author, year, publication, country), population (demographic characteristics, severity of stuttering - SSI-3 and SSI-4[23,24]), intervention (equipment, manner of presentation - mono or binaural, delay and frequency shift values), form of evaluation (whether independent or paired, for example), outcomes of changes in frequency of disfluency and naturalness of speech.

Meta-analysis

After the systematic gathering of the variables of interest, we conducted a meta-analysis to integrate the results and reach a final conclusion regarding the benefit of AAF.

We analyzed the effect of the interventions in percentage points (PP), based on the difference between the mean disfluency frequency of post- and pre-treatment conditions. The compared conditions included physiological auditory feedback (control condition) and altered auditory feedback immediately after the adaptation of a device. Considering that different speaking tasks can influence fluency, this study evaluated separately the results for the tasks: oral reading, monologue, conversation and telephone conversation. In studies that provided only individual data, the mean and standard deviation were calculated for the participants' age and for the frequency of disfluencies. When necessary, standard errors were converted to standard deviations. We calculated the difference between the means and between the standard deviations for the percentage of stuttered syllables (%SS) or percentage of stuttered words (%SW) before and after the AAF adaptation. For studies that presented data in graphs, the WebPlotDigitizer program[23-25] (available at: https://automeris.io/WebPlotDigitizer/) was used to extract the data from the graphs.

In studies that assessed outcomes using a spontaneous speech task, the methods were reviewed carefully to determine whether there was evidence of an active interlocutor. If yes, the task was considered a conversation, and if no, it was considered a monologue. Studies that presented both stuttered and common disfluencies, the data relative to stuttered disfluencies were considered. For studies that used the same sample of subjects for different evaluation conditions (e.g., different delay settings, comparisons between the effects of different DAF+FAF combinations, or evaluations with devices from different brands), the condition that generated the largest effect size was considered.

We anticipated that a factor of heterogeneity could be the speech task, so the studies were distributed in subgroups (reading, monologue, conversation, and telephone conversation). Meta-regression for age, sex, and disorder severity was conducted. For severity analysis we considered the proportion of subjects classified with (1) very mild to moderate and (2) moderate or more in the total sample of each study. Subgroup analyses were performed to assess the impact of device configuration (DAF, FAF, DAF+FAF) and for use of active speech pattern alteration techniques. Sensitivity analysis was performed by excluding the largest and smallest effect size studies per speech task, evaluating the new effect estimate and the confidence interval with the estimated effect generated by all studies in the sample. Publication bias was assessed using the Egger's regression test.

The risk of bias in included studies was assessed as recommended by the Cochrane Collaboration[25] using the Robins-I tool (Risk Of Bias In Non-randomized Studies of Interventions)[26]. Two reviewers (GB and MET) independently applied the tool to each included study and recorded notes and rationale on their judgments. Any discrepancies in judgments were resolved by consensus between the two authors; if necessary, a third author (BCB) reviewed the notes and defined the risk of bias.

Because the effect of AAF shows variation between subjects and prognostic factors are unclear, the random-effects model and the inverse variance method were applied to calculate the mean distribution of the expected effect size. The impact of heterogeneity between studies was calculated by the tau2 (estimated by DerSimonian-Lair), I2, and Q statistics; 95% CIs around tau-squared and I-squared were calculated to judge our confidence about these metrics (Jackson Method). All analyses were run in RStudio software (Version 1.2.5033) and conducted by the meta package (version 4.19-2)[26].

Results

A total of 1,639 studies were identified from the initial database search. After the removal of duplicates, 1,490 studies were evaluated based on their titles and abstracts. Of these, 115 were included for full-text evaluation, and in the end, 26 studies were included[6,16-18,27-47]. The references of the included articles were evaluated for potential studies, and one additional study was detected, bringing the total to 27 studies. The selection process and justifications for exclusion can be seen in the flow diagram (Figure 1) according to PRISMA.

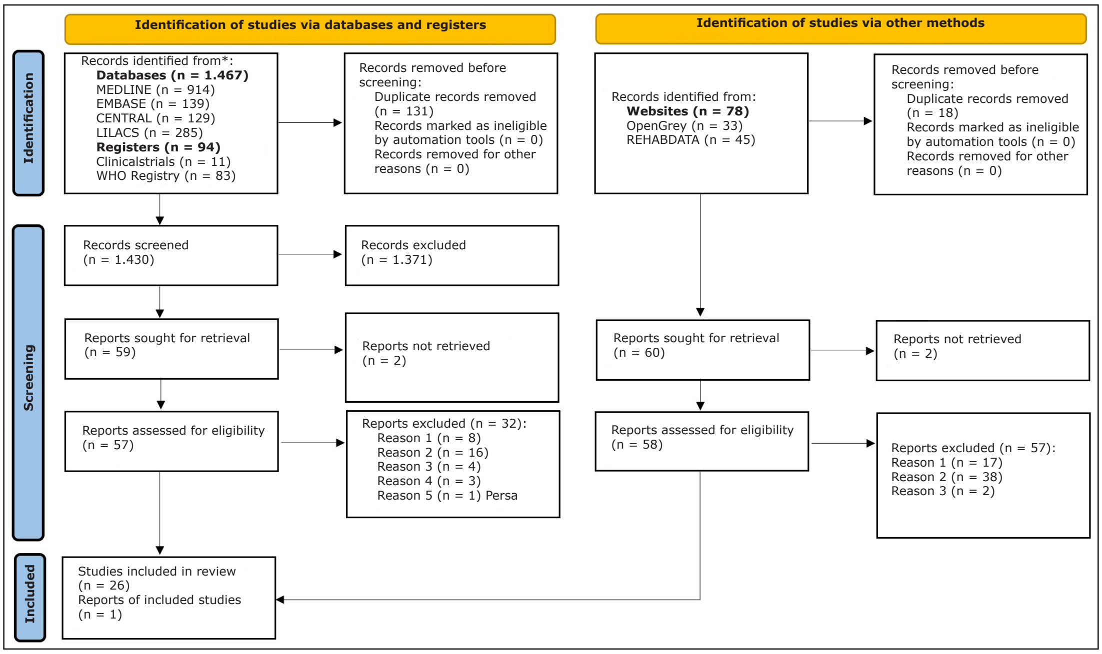

Figure 1. Flowchart of identification, eligibility and inclusion of articles.

In addition to the articles written in Portuguese, English, and Spanish, one article in German[38] was included in this review, with analysis assisted by a bilingual researcher (Portuguese-German). One protocol study (IRCT2014061618107N1) identified in the search had its results reported in an article published in Persian[31]. The author was contacted, and he provided us with the doctoral thesis that resulted in the article published in English, from which the data were extracted[48]. Of the two studies that appeared to meet the inclusion criteria, one was excluded because it assessed disfluency duration and rate, but not disfluency frequency[49]; the other conducted the assessment during the two weeks following the loan of the device, not within the assessment period of this study[50].

Twenty-five studies have evaluated the frequency of disfluencies, assessing the same subjects before the use of AAF and immediately after AAF adaptation[16-18, 20,27-30,32-43,45-48,51]. Four studies have evaluated the naturalness of speech immediately after the adaptation of an AAF device[6,27-28,44]. The characteristics of the studies are presented by outcome: speech fluency (Table 1) and naturalness of speech (Table 2).

Table 1. Studies that assessed frequency of disfluencies after AAF adaptation

Study	Sample Characterization	Device settings	Setting and speech task	Speech fluency outcomes
Pollard *et al*., 2009.[16]	N=11 (6 men) Mean age = 34.2 years Max-min = 18-62 years	SpeechEasy DAF+FAF 60ms + 500Hz (mode)	Within the clinic Oral reading Conversation DLS Questions to strangers	The immediate effect is a cross-section of the data presented in this study. Using the AAF in oral reading resulted in a mean age decrease of 58%SS, in conversation 15% SS and asking questions/maintaining a conversation with a stranger was 2%SS.
Chambers *et al*., 2009.[17]	N=9 Mean age = 29.89 years Max-min = 21-46 years	TAD* DAF+FAF -56ms+304Hz	Within the clinic Telephone conversations	AAF showed an immediate decrease of 32%SS in telephone conversations, the best response was 67%SS decrease (by 2 subjects). Two subjects showed an increase of 8-9%SS.
Hudock & Kalinowski 2014.[18]	N=9 (8 men) Mean age = 35.1 years Max-min = 21-72 years	DSP-1** DAF+FAF COMBO-2 COMBO-4	Within the clinic Telephone conversations	The use of AAF showed a mean decrease of 72%SS in both situations; in addition, the COMBO-4 condition showed significantly gre-ater effect (74%SS) compared to COMBO-2 (63%SS). COMBO-2> -50ms+1/2 octave / COMBO-4> -200-1/2 octave+COMBO2
O'Donnell *et al*., 2008.[20]	N=7 (5 men) Mean age = 36 years Max-min = 24-53 years	SpeechEasy DAF+FAF 30ms + 500Hz 30ms + 0Hz (mode)	Within the clinic Oral reading Monologue	The immediate effect is a cross-section of the data presented in this study. In oral reading (N=5) the device resulted in a decrease of 84.1%SS and 62.6%SS for 2 subjects; 3 subjects showed - 1%SS with and without AAF; 2 subjects had difficulty reading age-appropriate passages and were excluded. In monologue (N=7) all participants showed improvement, ranging from 75.5%SS to 97.9%SS. The subjects were trained to perform pro-longation at the beginning of phonation; the use of the technique afterwards was at each subject's criteria.
Stuart *et al*., 2006.[28]	N=9 (8 men) Mean age = 29.11 years Max-min = 10-55 years	SpeechEasy DAF+FAF -60ms+500Hz	Within the clinic Oral reading Monologue	The immediate effect is a cross-section of the data presented in this study. The use of AAF showed a reduction of appro-ximately 85%SS in oral reading and 75%SS in monologue. Minor speech changes were encouraged to enhance the AAF, such as vowel prolongation and use of "um" or "ah" at the beginning of the sentence.
Armson *et al*., 2006.[29]	N=13 (11 men) Mean age = 35.5 years Max-min = 21-54 years	SpeechEasy DAF+FAF -60ms+500Hz	Within the clinic Oral reading Monologue Conversation	AAF: 74%SS reduction in oral reading, 36%SS in monologue and 49%SS in conversation. AAF + Vowel prolongation: 42%SS reduction in oral reading, 30%SS in monologue and 36%SS in conversation.
Antipova *et al*., 2008.[30]	N=8 (7 men) Mean age = 35 years Max-min = 16-55 years	The Pocket Speech Lab DAF+FAF 9 conditions	Within the clinic Oral reading Monologue	The study was conducted in 3 sessions (1 introductory and 2 assessment sessions). It shows that different combinations of DAF+FAF produce distinct results on fluency: DAF 75ms decreased 35%SS; DAF 75ms + FAF -1/2 octave reduced 44%SS (considered in the meta-analysis of this study).
Armson & Kiefte, 2008.[32]	N=31 (20 men) Mean age = 27.7 years Max-min = 18-51 years	SpeechEasy DAF+FAF -60ms+500Hz (mode)	Within the clinic Oral reading Monologue	In oral reading the decrease ranged from 16.5%SS (n=1) to 100%SS (n=7), the ma-jority (75.4%) showed improvement equal to or greater than 80%SS. One showed no im-provement and another had a slight worsening in disfluencies. In monologue, the decrease ranged from 75.4%SS (n=1) to 100%SS (n=4), 8 subjects showed improvement equal to or greater than 80%SS. One participant showed worsening in disfluencies.
Buzzeti *et al*., 2016.[33]	N=16 Mean age = 11 e 11,5 years Max-min = 8-17 years	FonoTools DAF	Within the clinic Oral reading	The DAF resulted in a 34.87% and 22.27% reduction in stuttering disfluencies in the moderate and severe/very severe stuttering group, respectively.

Study	Sample Characterization	Device settings	Setting and speech task	Speech fluency outcomes
Fiorin *et al*., 2021.[34]	N=16 (11 men) 8-17 years G. Moderada G. Severa	Fonotools DAF -100ms	Within the clinic Spontaneous speech	Severe stuttering group: reduction of stuttering disfluencies. In both groups: there was no statistically significant difference between NAF and DAF regarding total disfluencies or other disfluencies.
Foundas *et al*., 2013.[35]	N=14 Mean age = 37.21 years	SpeechEasy DAF+FAF -60ms+500Hz Custom Fitting	Within the clinic Oral reading Monologue Conversation with question script	Custom fitting: decrease of 52%SS and 57%SS in oral reading; 42%SS and 32%SS in monologue; and 30%SS and 35%SS in conversation (right and left ears respectively). The Custom fitting showed greater effect than the standard one. In conversation, adaptation in the left ear seemed to induce a greater benefit.
Gallop *et al*., 2012.[36]	N=11 (7 men) Mean age = 28 years Max-min = 11-51 years	SpeechEasy DAF+FAF -150ms+500Hz	Within the clinic Conversation	The immediate effect is a cross-section of the data presented in this study. The use of AAF showed a significant reduction in %SS: in NAF a mean of approximately 15.7%SS was observed, with AAF this mean decreased to approximately 4%SS. Data extracted by the authors of this review from Figure 1 of the original article.
Lincoln *et al*., 2010.[37]	N=11 (7 men) Mean age = 40 years Max-min = 21-65 years	Pocket Speech Lab DAF+FAF 5 conditions	Within the clinic Oral reading Conversation	Study found wide variation in response to AAF between subjects. A mean decrease of 62%SS and 49%SS occurred, in oral reading and conversation respectively, with the combo with the greatest effect (100ms-1 octave).
Natke, 2000.[38]	N=12 men mean age = 33.1 years	DFS 404 DAF -53ms FAF -1/2 octave	Within the clinic oral reading	FAF: mean decrease of 19.5%SS; 4 subjects showed no improvement; and 4 subjects presented less than 3%SS. DAF: mean decrease of 44.4%SS; %SS decreased to some extent in all subjects; 6 subjects have less than 3%SS.
Picoloto *et al*., 2017.[39]	N=20 (men and women) Mean age = 11 years Max-min = 7-17 years	FonoTools DAF 100ms	Within the clinic Spontaneous speech	PWS without CAPD: a tendency was observed for a reduction in the disfluencies typical of stuttering, mainly as regards blocks and repetitions of monosyllabic words. PWS with CAPD: a tendency towards a reduction in the speech rate was observed. No significant effect on the frequency of disfluencies and speech rate.
Ratyńska *et al*., 2012.[40]	N=335 (268 men) Mean age = 17.9 years Max-min = 6-64 years	Digital Speech Aid Different conditions	Within the clinic Oral reading Monologue Conversation	For all speech tasks there was statistically significant improvement, and in most cases the improvement was moderate or medium. More than 80% of the sample showed improvement with the device, however 15% to 19% of the subjects showed no positive effect or even an increase in disfluencies with the use of the AAF.
Ritto *et al*., 2016.[41]	N=11 (10 men) Mean age = 30 years	SpeechEasy DAF+FAF -60ms+500Hz	Within the clinic Oral reading Monologue Conversation	The immediate effect is a cross-section of the data presented in this study. The use of AAF showed a reduction of approximately 40%SS and this effect was maintained at follow-up. One subject had no benefit from the use of AAF.
Saltuklaroglu *et al*., 2009.[42]	N=10 (9 men) Mean age = 30.42 years 18-51 years	Digitech Studio S100 4 conditions	Within the clinic Oral reading	Mean reduction of 68%SS. By condition, AAF showed a reduction of: 73%SS with FAF +1/2 and DAF 100ms; 66%SS with DAF 200ms; and 62%SS with FAF -1/2.
Sparks *et al*., 2002.[43]	N=4 men age = 13-19-19-21 years	Phonic Mirror Mini DAF 55 DAF 80 DAF 105	Within the clinic oral reading monologue	Two subjects with mild stuttering showed minimal improvement with DAF at both speech rates. Two subjects with severe stuttering showed significant improvement with all the DAF settings and at both normal and fast speech rates.
Stuart *et al*., 2004.[44]	N=7 (6 men) Mean age = 21.85 years 12–34 years	SpeechEasy DAF+FAF -60ms+500Hz	Within the clinic oral reading Monologue	The immediate effect is a cross-section of the data presented in this study. The use of AAF had a reduction of approximately 90%SS in oral reading and 67%SS in monologue.
Stuart *et al*., 2008.[45]	N=12 (10 men) Mean age = 35 years Max-min = 20-50 years	Studio-master Model FAF +1/4 octave -1/4 octave	Within the clinic Oral reading	With a mean reduction of 50%SS in reading, the duration of residual stuttering decreased by a mean of 20%. The proportion of disfluency types (prolongations, repetition, or blocking) showed no difference.

Study	Sample Characterization	Device settings	Setting and speech task	Speech fluency outcomes
Unger *et al*., 2012.[46]	N=30 (23 men) Mean age = 36.5 years Max-min = 18-68 years	VA 601i Fluency Enhancer 50ms + 250Hz SmallTalk 50ms-0.4 octave	Within the clinic Oral reading Monologue Conversation	Oral reading: decrease in %SG without statistical significance for the mild severity group and significant for the severe group. Monologue and conversation: significant difference in %SS for both mild and severe severity. Both devices resulted in a very similar decrease in disfluency frequency.
Verdurand *et al*., 2020.[47]	N=21 (14 men) Mean age = 30.33 years Max-min = 17-46 years	MaxMSP Software 60ms -1/4 octave	Within the clinic Oral reading Spontaneous speech	In NAF subjects had a mean of 5.84%SS and with AAF 0.50%SS; 15 subjects reduced the percentage of disfluencies to zero; 2 subjects to less than 1%SS; 3 subjects to less than 2%SS; and 1 subject had worsening fluency. Mean calculated by the authors of this review considering the data in Table 4 of the original article; data were not presented by speech task.
Arbabshirani *et al*., 2014.[48]	N=22 (18 men) Mean age = 26.41 years Max-min = 17-44 years	Fluency Coach Software 6 conditions	Clinica Monologue	The use of AAF resulted in a mean decrease of 54%SS (min 10%SS, max 100%SS) immediately after the adaptation. The conditions in which fluency improvement was significant were: DAF 65ms; DAF 75ms; DAF 65ms and FAF -1/2 octave; DAF 75ms and FAF +1/2. Interestingly: The subjects underwent AAF in 2 different sessions, with a 10-day difference between each session, and the condition that induced maximum fluency varied for the same subject in both sessions, only 3 subjects maintained the condition with maximum fluency.
Buzzeti *et al*., 2018.[51]	N=30 Mean age = 17.8 years Max-min = 8 – 46 years	Fonotools DAF -100ms	Within the clinic Monologue	It showed a significant decrease in %SW in all those with severe stuttering, in 71.4% of those with mild stuttering, and 54% of those with moderate stuttering; it did not show significant reduction in disfluencies with duration (such as blocking, prolonging and pauses).

*TAD (Telep. Assistive Device) is a device that is connected directly to the telephone, which receives the individual's voice through a microphone and modifies the auditory signal, then returns the changed signal via a monaural headset.
** DSP-1 is a digital signal processor
N - Number of participants; DAF - Delay Auditory Feedback; FAF - Frequency Auditory Feedback; AAF - Altered Auditory Feedback; NAF - Non-altered Feedback; %WS - Percentage of Words Stuttered; %SS – percentage of syllables stuttered; DLS - daily life situations; CAPD - central auditory processing disorder.

Table 2. Studies that assessed speech naturalness after aaf adaptation

Study	Sample Characterization	Speech task and judges	Speech naturalness
Van Borsel *et al.*, 2008.[6]	PWS group with AAF 90ms (mode) N=8 (3 males) Mean age = 27.3 years Fluent group N=8 (4 males) Mean age = 25.6 years	Oral reading speech samples were randomly selected without the AAF and immediately after fitting. Evaluators: 14 PQG; 14 Speech Language Pathologists and 14 naïve adults.	There is a difference between evaluators, with naive adults being more severe in judgment (mean 7.32±0.83), followed by speech-language pathologists (mean 6.64±1.14) and then PWS (mean 5.46±1.05). Speech samples from fluent subjects were judged significantly more natural than samples from individuals who stutter even with AAF (mean 2.76±1.14 by naive adults).
Stuart *et al.*, 2004.[27]	PWS group with AAF (50 ms - 1/2 octave) N=10 (8 men) Mean age = 21.1 years PQG group with PFSP N=10 (5 men) Fluent Group N=5 (4 men) Mean age = 42 years	Oral reading speech samples were randomly selected from fluent, PWS subjects pre and post AFF fitting (DAF and FAF) and PWS pre and post PFSP therapy. Evaluators: 35 naïve young adults.	PWS group with AAF: speech significantly more natural than without; speech with DAF judged significantly more natural than with FAF; significantly more natural than PFSP group post therapy. Speech samples from fluent subjects were judged significantly more natural than samples from PWS, even with AAF and post-therapy.
Stuart *et al.*, 2006.[28]	PWS with AAF 60ms+500Hz N=9 (8 males) Mean age = 29.11 years	Oral reading and monologue speech samples were randomly selected without the AAF and immediately after fitting. Evaluators: 27 naïve young adults.	Without the device mean speech naturalness was approximately 7.15 and 6.15 points for monologue and reading, respectively; with the device it was judged significantly more natural, approximately 3.95 in both speech situations, immediately after adaptation. Data extracted by the authors of this review from Figure 3 of the original article.
Stuart *et al.*, 2004.[44]	PWS Adults Group 60ms+500Hz N=4 Mean age = 38 years PWS Youth Group 60ms+500Hz N=4 Average age= 12.5 years	Oral reading and monologue speech samples were randomly selected without the AAF and immediately after fitting Evaluators: 15 naïve young adults.	PWS Adults Group: average speech naturalness was approximately 8.15 and 5.75 points for monologue and reading, respectively, without the device; immediately after the adaptation speech was judged significantly more natural, between 3 and 4 points. PWS Youth group: average speech naturalness in both oral reading and monologue was judged between 5 and 6 points without the device; immediately after the adaptation it was judged significantly more natural, between 3 and 4 points. Data extracted by the authors of this review from Figure 3 of the original article.

PQG – Person who stutters; AAF - Altered Auditory Feedback; DAF - Delay Auditory Feedback; FAF - Frequency Auditory Feedback; PFSP - Precision Fluency Shaping Program.

Its is important to mention that, of the studies included in the systematic review that assessed frequency of disfluencies, one study compared the use of AAF between PWS with and without central auditory processing disorder[39], one compared the effect on French and Italian speakers[47]; and another compared the effects of two different devices on the same sample[46]. Few studies have presented an analysis based on the severity of the disorder[33-,34,46]. All studies performed the speech tasks within a clinic setting, except for one that evaluated conversation with strangers in the clinic hallways[16].

The frequency of disfluencies was primarily evaluated in oral reading, followed by monologue. Among the studies we considered that employed monologue, three were originally described as using spontaneous speech[34,39,51]; however, for this review, we classified them as monologue due to the evidence of the absence of an active interlocutor. Face-to-face and telephone conversations were the least evaluated tasks.

Three studies have associated AAF with active speech pattern modification techniques[20,28-29]. Speech was judged to be significantly more natural with AAF than without it in all studies[6,27-28,44], but not as natural as the speech of fluent subjects[6,44]. Furthermore, speech naturalness varied by rater, with naïve adults rating the speech as the least natural[6].

The risk of bias per study ranged from low to moderate, and the overall risk of bias was moderate, as shown in Table 3. When the risk was assessed by outcome (frequency of disfluencies and naturalness of speech), both were considered to be of moderate risk (Table 4).

Table 3. Risk of bias assessment by study

Estudo	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall bias
Van Borsel *et al*., 2008.[6]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Pollard *et al*., 2009.[16]	Moderate	Low	Low	Moderate	Low	Low	Low	**Moderate**
Chambers *et al*., 2009.[17]	Moderate	Low	Low	Low	Moderate	Low	Low	**Moderate**
Hudock & Kalinowski 2014.[18]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
O'Donnell *et al*., 2008.[20]	Moderate	Low	Low	Moderate	Low	Low	Low	**Moderate**
Stuart *et al*., 2004.[27]	Moderate	Low	Low	Moderate	Low	Low	Low	**Moderate**
Stuart *et al*., 2006.[28]	Moderate	Low	Low	Moderate	Low	Low	Low	**Moderate**
Armson *et al*., 2006.[29]	Moderate	Low	Low	Moderate	Low	Low	Low	**Moderate**
Antipova *et al*., 2008.[30]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Armson & Kiefte, 2008.[32]	Moderate	Low	Low	Moderate	Low	Low	Low	**Moderate**
Buzzeti *et al*., 2016.[33]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**
Fiorin *et al*., 2021.[34]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**
Foundas *et al*., 2013.[35]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Gallop *et al*., 2012.[36]	Moderate	Moderate	Low	Low	Low	Low	Low	**Moderate**
Lincoln *et al*., 2010.[37]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Natke, 2000.[38]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**
Picoloto *et al*., 2017.[39]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**
Ratyńska *et al*., 2012.[40]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**
Ritto *et al*., 2016.[41]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Saltuklaroglu *et al*., 2009.[42]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Sparks *et al*., 2002.[43]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Stuart *et al*., 2004.[44]	Moderate	Low	Low	Moderate	Low	Moderate	Low	**Moderate**
Stuart *et al*., 2008.[45]	Moderate	Low	Low	Moderate	Low	Low	Low	**Moderate**
Unger *et al*., 2012.[46]	Moderate	Low	Low	Low	Low	Low	Low	**Moderate**
Verdurand *et al*., 2020.[47]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**
Arbabshirani *et al*., 2014.[48]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**
Buzzeti et al., 2018.[51]	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**

Table 4. Risk of bias evaluation by outcome

Domain	Speech fluency	Speech naturalness
Bias due to confounding	Moderate	Moderate
Bias in selection of participants into the study	Moderate	Moderate
Bias in classification of interventions	Low	Low
Bias due to deviations from intended interventions	Moderate	Low
Bias due to missing data	Moderate	Low
Bias in measurement of outcomes	Moderate	Low
Bias in selection of the reported result	Low	Low
Overall bias	Moderate	Moderate

Twenty studies were included in the meta-analysis[16-18,20,27-30,32-33,36-42,46,48,51] (Figure 2). The conditions that generated the greatest effect and were considered in this meta-analysis were: COMBO 4[18], condition 5[37], DAF 100ms[42], DAF 75ms[48], DAF 75ms with FAF -1/2 octave[30], SmallTalk equipment[46]. Five studies were not included in the meta-analysis for the following reasons: it did not separate the results by speech task, presenting the percentage of stuttered syllables for reading and spontaneous speech together[47]; it was not possible to extract the data safely and accurately from the graph[34,43]; it did not present sufficient data on the outcome of interest (e.g., standard deviation or standard error)[35,45]. Also, some studies investigated more than one group of people, and these were included separately in the meta-analysis: Unger 2012 investigated (a) subjects with mild stuttering, (b) moderate to severe[46]; Picoloto 2017 (a) PWS with central auditory processing disorder, (b) PWS without central auditory processing disorder[39]; Buzzeti 2016 (a) moderate severity, (b) severe or very severe[33].

Subgroup analysis for oral reading resulted in a mean decrease of 6.39 percentage points (PP) (95% confidence interval [-9.41; -3.36]; I2 90%; 12 studies, 525 subjects); in monologue a mean decrease of 6.15 PP (95% confidence interval [-9.22; -3.08]; I2 90%; 12 studies, 522 subjects); in conversation a mean decrease of 6.22 PP (95% confidence interval [-11.75; -0.70]; I2 96%; seven studies, 451 subjects); in telephone conversation a mean decrease of 12.14 PP (95% confidence interval [-24.39; 0.10]; I2 91%; two studies, 18 subjects). Heterogeneity was high in all assessments. No significant difference was found between speech tasks (p= 0.8317).

Meta-regression revealed the following findings: age did not show statistical significance in reading (p=0.7630) and monologue (p=0.7164) tasks, but was significant in conversation (p<0.0001), with a smaller effect size in adolescents. Sex was not a factor of heterogeneity in the three situations analyzed: reading (p=0.7944), monologue (p=0.8049) and conversation (p=0.8967). The severity of the disorder was assessed by the SSI-3 or SSI-4 in all studies, except one, which used self-assessment[20]. Moderate or severe severity of the disorder showed statistical significance in conversation (p=0.0233) and monologue (p=0.0522), but not in reading (p=0.2816).

In the subgroup analysis, only the comparison between DAF and DAF+FAF was performed, with significant results for monologue (p=0.0113) and non-significant for reading (p=0.2629); in conversation, this analysis was not possible, since all studies used DAF+FAF.

The analysis of the use of changes in speech pattern, such as prolongations at the beginning of phonation and the use of initiators such as “um” and “ah”, was not significant in reading (p=0.1972) and monologue (p=0.1331). The studies that associated these techniques with the use of AAF did not evaluate conversation.

In sensitivity analyses, studies with potential bias - such as those with larger and smaller effect sizes - were removed, and the mean effect variation remained within the confidence interval of the initial meta-analysis. Publication bias was verified using Egger’s regression test which allowed to conclude the absence of publication bias for reading (t = -1.74, df = 12, p-value = 0.1075); monologue t = -1.53, df = 12, p-value = 0.1522) and conversation (t = -1.34, df = 6, p-value = 0.2283).

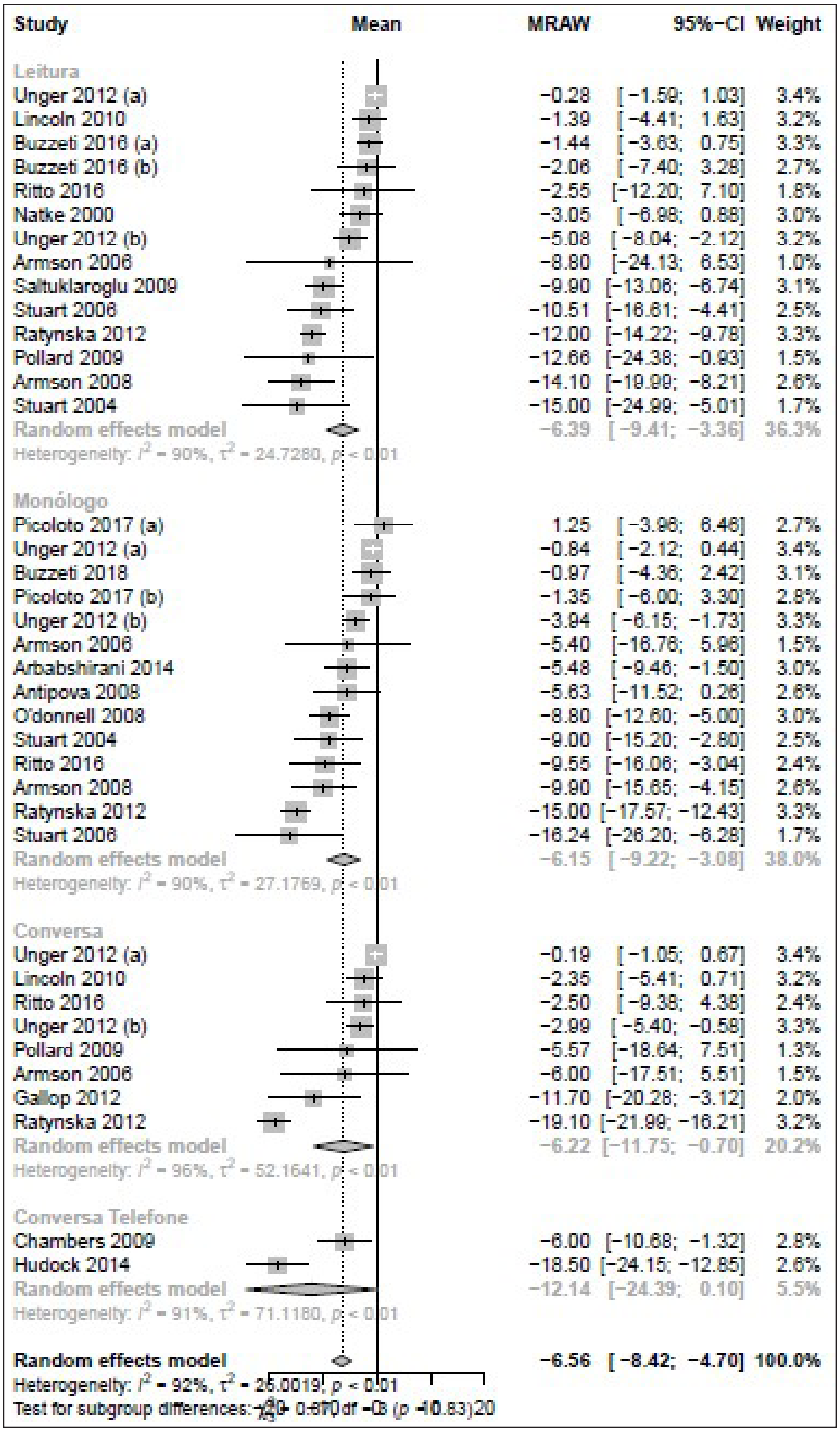

Figure 2. Meta-analysis of the immediate effect of auditory feedback alteration - percentage of disfluencies in stutter

Discussion

This systematic review and metanalysis aimed at assessing the short-term impact of AAF (with focus on DAF and FAF) in treating developmental stuttering in both adults and children. The results showed that there was an immediate and positive effect in the use of AAF for the treatment of stuttering, however there is an evident and important heterogeneity in the size of the AAF effect.

The literature shows that the speech task is a factor treated as a source of heterogeneity in the effect of using AAF[16,28,29,32,35,37,46]. In this review, the difference between the speech tasks did not demonstrate statistical significance, in line with other primary studies[27,30,41.] However, due to the presentation of the data in the original articles and seeking to avoid biases, the outcome of the frequency of disfluencies was evaluated by speech task.

Severity of the disorder also contributed to heterogeneity in effect size (i2=92%), as subjects with fewer disfluencies often showed less response to device use compared to those with more severe cases[29,34,35,43,46,51]. In this review's meta-regression, severity was statistically significant for spontaneous speech tasks (monologue and conversation). This suggests that AAF is more suitable for individuals with moderate to severe disfluency.

A possible heterogeneity factor poorly investigated so far is the central auditory processing disorder (CAPD). One study evaluated the response of two PWS groups (total of 20 subjects), one group with and one without CAPD, to auditory feedback delay (DAF of 100ms), and among its findings it found that the group without CAPD showed a statistical trend (p=0.058) of reduced stuttered disfluencies, and the group with CAPD did not[39]. In this review this was the only group that did not show some level of improvement in speech fluency with AAF - Picoloto 2017 (a) in Figure 2. Considering that auditory abilities can influence the effect of auditory feedback, their impact on the effect size of using altered auditory feedback should be investigated.

One review from 2006 did not recommend the use of AAF in children[8] (younger than nine years old) because in a previous study, subjects aged nine to eleven years did not respond as well as adult participants[54]. Another study evaluated the effect of DAF+FAF in adults versus adolescents (mean age of 12.5 years, with a standard deviation of 2.6) and found no significant difference between responses[27]. In this review, only four studies[33,39,40,51] included subjects younger than nine years, and the data are published as mean results, making a more precise evaluation impossible. In our meta-regression, age was shown to be significant in conversational outcomes; however, the number of subjects under the age of nine is uncertain (only 16 subjects are known to have been evaluated in two studies[33,51]). Given the limited data available to understand the effect size of AAF in children under nine years of age, and the fact that younger participants were shown to be statistically significant in conversation, this review supports the previous review's[8] recommendation against the use of AAF in children under nine years old.

DAF+FAF combination was the most used in studies, followed by DAF, and only three used the FAF alone - and only in oral reading[38,42,45]. According to the subgroup analysis DAF+FAF demonstrated statistical significance for a larger effect size when compared to DAF in monologue, but not in reading; and all studies that evaluated conversation used DAF+FAF. Prior to the 2000s one study evaluated the effect of DAF+FAF and found no significant difference between the combo and DAF and FAF alone[13].

The most used DAF+FAF configuration was 60 ms delay with plus 500 Hz in frequency configuration normally used in SpeechEasy[16,27-29,32,35,41]; isolated DAF ranged from 30 ms[19] to 200 ms[42] with the most frequent being 100 ms[34,39,51]; isolated FAF ranged from minus 1/4 and 1/2 octave[38,42] to plus 1/4 and ½ octave[42,45]. The majority of devices were used with binaural feedback in studies that did not use SpeechEasy; when monaural, one study evaluated right vs. left ear fitting and found that in conversation left ear fitting seemed to induce greater benefit[35], counterpointing a previous study that found no difference between ears[15]. The intensity that the auditory signal presented is usually the hearing level that the subject feels comfortable with[27,34,41].

Studies have sought to identify the ideal delay and frequency change for maximum fluency[8], suggesting a 50 ms delay and ¼ octave change[15], but the response to AAF continued to show great variability between subjects. One study compared the effect size of AAF using standard versus custom settings and found a significant difference, with custom settings having a greater impact on speech fluency[35]. Another study evaluated the same subjects in two sessions, 10 days apart, using six different conditions (DAF and DAF+FAF) and found that the conditions inducing maximum fluency varied between sessions for most participants[47]. These studies suggest that individual variability is greater than expected, and a pre-established standard setting may not provide the maximum fluency AAF can offer. Additionally, especially in long-term studies, a subject's response may vary day-to-day, indicating that users might benefit from more autonomy to adjust their device's auditory feedback settings.

For speech naturalness, studies have confirmed that PWS speech is rated significantly more natural with AAF than without. However, even with the device, it is still judged as less natural compared to fluent speakers.[6,27,28,44]. On a scale of 1 to 9[5], participants judged the speech of PWS using DAF as less natural compared to the speech of fluent individuals[6]. Furthermore, the perception of speech naturalness did not vary between the use of FAF and DAF in subjects with mild or severe stuttering[44].

Limitations of the evidence included in this review were the wide heterogeneity of response to AAF use without clear and evident explanation. All studies presented assessments carried out within the clinic and it is known that the subject's response in the controlled environment tends to be better than in real-life situations[20,52]. In the analysis of the severity of the disorder, some studies had to be excluded because they did not present this data, reducing the sample to 12 studies.[16,17,20,27,28,30,33,38,41,46,48,51]. Only two studies evaluated the effect on telephone conversation[17,18] and few considerations about this speech task could be made. And the common presentation of data by general sample average makes the analysis of secondary studies impossible and biased.

Limitations of the review process used include the fact that, although study selection was performed independently and in pairs, data extraction and risk of bias assessment were conducted by a single author (GB). Subsequently, another author (MET) reviewed the data extraction and the plausibility of the risk of bias assessment in the included studies. This approach may limit consistency and objectivity in the analysis, since data extraction and bias assessment ideally require multiple raters to reduce potential bias and increase the reliability of the results.

As a suggestion for future research: evaluate the impact of CAPD on the response to the use of AAF in PWS; explore the variability of subjects' response; present data by subject including age, education, severity of the disorder and frequency of dysfluencies among others so that studies with secondary data are less susceptible to bias, since the joint evaluation of the primary studies will be essential to understand the sources of heterogeneity of response to treatment.

Conclusion

Auditory feedback modification, used as a method to improve speech fluency and naturalness in individuals who stutter, has demonstrated positive short-term effects. However, the size of the effect on speech fluency varies greatly among subjects, with those with moderate or severe disorders tending to have a more favorable response. The combination of DAF and FAF also appears to benefit these individuals. Furthermore, the use of auditory feedback modification in young people (approximately between 9 and 13 years old) should not be considered the first treatment option, since these subjects generally do not have as effective a response as adults.

References

1. World Health Organization. The ICD-10 classification of mental and behavioural disorders: clinical descriptions and diagnostic guidelines. Geneva (Switzerland): World Health Organization. 1992.

2. Yairi E, Ambrose N. Epidemiology of stuttering: 21st century advances. J Fluency Disord. 2013; 38(2): 66-87.

3. Perez, H. R., & Stoeckle, J. H. (2016). Stuttering: Clinical and research update. Canadian family physician Medecin de famille canadien, 62(6), 479–484.

4. Mølgaard, T. B., & Baandrup, L. (2024). Developmental stuttering in adults. Ugeskrift for laeger, 186(35), V03240229. https://doi.org/10.61409/V03240229

5. Martin RR, Haroldson SK, Triden KA. Stuttering and speech naturalness. J Speech Lang Hear Res. 1984; 49(1): 53-8

6. Van Borsel J, Eeckhout H. The speech naturalness of people who stutter speaking under delayed auditory feedback as perceived by different groups of listeners. J Fluency Disord. 2008; 33(3): 241-51.

7. Perez, H. R., & Stoeckle, J. H. (2016). Stuttering: Clinical and research update. Canadian family physician Medecin de famille canadien, 62(6), 479–484.

8. Lincoln M, Packman A, Onslow M. Altered auditory feedback and the treatment of stuttering: A review. J Fluency Disord. 2006; 31(2): 71-89.

9. Kern, A. Der Einfluss des Hoerens auf das Stottern. Arch. Psychiat. Nervenk. 1932; 97: 429–450.

10. Kalinowski J, Armson J, Stuart A, Gracco VL. Effects of alterations in auditory feedback and speech rate on stuttering frequency. Lang Speech. 1993; 36(1):1-16.

11. Chang HJ. A study of disfluency characteristics according to auditory feedback condition. J of Speech. 2020; 29(4):13-23.

12. Andrade CRFD, Juste FS. Systematic review of delayed auditory feedback effectiveness for stuttering reduction. J Soc Bras Fonoaudiol. 2011; 23(2):187-191.

13. Macleod J, Kalinowski J, Stuart A, Armson J. Effect of single and combined altered auditory feedback on stuttering frequency at two speech rates. J Commun Disord. 1995; 28(3): 217-228.

14. Kalinowski J, Stuart A, Sark S, Armson, J. Stuttering amelioration at various auditory feedback delays and speech rates. Int J Lang Commun Disord. 1996; 31(3): 259-269.

15. Stuart A, Kalinowski J, Rastatter MP. Effect of monaural and binaural altered auditory feedback on stuttering frequency. J Acoust Soc Am. 1997; 101(6): 3806-9.

16. Pollard R, Ellis JB, Finan D, Ramig PR. Effects of the SpeechEasy on objective and perceived aspects of stuttering: a 6-month, phase I clinical trial in naturalistic environments. J Speech Hear Res. 2009; 52: 516–33.

17. Chambers N. Impact of the Telephone Assistive Device (TAD) on stuttering severity while speaking on the telephone. S Afr J Commun Disord. 2009; 56(1), 23-34.

18. Hudock D, Kalinowski J. Stuttering inhibition via altered auditory feedback during scripted telephone conversations. Int J Lang Commun Disord. 2014; 49(1):139-47.

19. Van Borsel J, Reunes G, Van den Bergh N. Delayed auditory feedback in the treatment of stuttering: clients as consumers. Int J Lang Commun Disord. 2003; 38(2):119-29.

20. O'Donnell JJ, Armson J, Kiefte M. The effectiveness of SpeechEasy during situations of daily living. J Fluency Disord. 2008; 33(2): 99-119.

21. Laiho, A., Elovaara, H., Kaisamatti, K., Luhtalampi, K., Talaskivi, L., Pohja, S., Routamo-Jaatela, K., & Vuorio, E. (2022). Stuttering interventions for children, adolescents, and adults: a systematic review as a part of clinical guidelines. Journal of communication disorders, 99, 106242. https://doi.org/10.1016/j.jcomdis.2022.106242

22. Andrade, C. R., & Juste, F. S. (2011). Análise sistemática da efetividade do uso da alteração do feedback auditivo para a redução da gagueira [Systematic review of delayed auditory feedback effectiveness for stuttering reduction]. Jornal da Sociedade Brasileira de Fonoaudiologia, 23(2), 187–191. https://doi.org/10.1590/s2179-64912011000200018

23. Tsafnat G, Glasziou P, Choong MK, Dunn A, Galgani F, Coiera E. Systematic review automation technologies. Systematic reviews. 2014; 3(1):1-15.

24. Drevon, D., Fursa, S. R., & Malcolm, A. L. (2017). Intercoder Reliability and Validity of WebPlotDigitizer in Extracting Graphed Data. Behavior modification, 41(2), 323–339. https://doi.org/10.1177/0145445516673998

25. Piotrowicz, K., Klich-Rączka, A., Skalska, A., Gryglewska, B., Grodzicki, T., & Gąsowski, J. (2022). Pulse Wave Velocity and Sarcopenia in Older Persons-A Systematic Review and Meta-Analysis. International journal of environmental research and public health, 19(11), 6477. https://doi.org/10.3390/ijerph19116477

26. Schwarzer G. meta: An R package for meta-analysis. R news. 2007; 7(3): 40-45.

27. Stuart A, Kalinowski J, Rastatter MP, Saltuklaroglu T, Dayalu V. Investigations of the impact of altered auditory feedback in-the-ear devices on the speech of people who stutter: initial fitting and 4-month follow-up. Int J Lang Commun Disord. 2004; 39(1): -113.

28. Stuart A, Kalinowski J, Saltuklaroglu T, Guntupalli VK. Investigations of the impact of altered auditory feedback in-the-ear devices on the speech of people who stutter: One-year follow-up. Disabil Rehabil. 2006; 28(12): 757-65.

29. Armson J, Kiefte M, Mason J, De Croos D. The effect of SpeechEasy on stuttering frequency in laboratory conditions. J Fluency Disord. 2006; 31(2):137-52.

30. Antipova EA, Purdy SC, Blakeley M, Williams S. Effects of altered auditory feedback (AAF) on stuttering frequency during monologue speech production. J Fluency Disord. 2008; 33(4): 274-90.

31. Arbabshirani N, Shafiei B, Marasi MR. Effects of Altered Auditory Feedback on Stuttering. MEJDS. 2014; 4(9): 01-09.

32. Armson J, Kiefte M. The effect of speecheasy on stuttering frequency, speech rate, and speech naturalness. J Fluency Disord. 2008; 33(2):120-34.

33. Buzzeti PBMDM, Fiorin M, Martinelli NL, Cardoso ACV, Oliveira CMCD. Comparison of reading of school-age children who stutter in two listening situations: usual and delayed. Rev CEFAC. 2016; 18(1): 67-73.

34. Fiorin M, Marconato E, Palharini TA, Picoloto LA, Frizzo ACF, Cardoso ACV, et al. Impact of auditory feedback alterations in individuals with stuttering. Braz J Otorhinolaryngol. 2021; 87(3); 247-54.

35. Foundas AL, Mock JR, Corey DM, Golob EJ, Conture EG. The SpeechEasy device in stuttering and nonstuttering adults: Fluency effects while speaking and reading. Brain Lang. 2013; 126(2):141-50.

36. Gallop RF, Runyan CM. Long-term effectiveness of the SpeechEasy fluency-enhancement device. J Fluency Disord. 2012; 37(4): 334-43.

37. Lincoln M, Packman A, Onslow M, Jones M. An experimental investigation of the effect of altered auditory feedback on the conversational speech of adults who stutter. J Speech Hear Res. 2010; 53:1122–31.

38. Natke U. Reduction of stuttering frequency using frequency-shifted and delayed auditory feedback. Folia Phoniatr Logop. 2000; 52(4):151-9.

39. Picoloto LA, Cardoso ACV, Cerqueira AV, Oliveira CMCD. Effect of delayed auditory feedback on stuttering with and without central auditory processing disorders. CoDAS 2017;29(6):e20170038 DOI: 10.1590/2317-1782/201720170038

40. Ratyńska J, Szkiełkowska A, Markowska R, Kurkowski M, Mularzuk M, Skarżyński H. Immediate speech fluency improvement after application of the Digital Speech Aid in stuttering patients. Med Sci Monit. 2012; 18(1): 9-12.

41. Ritto AP, Juste FS, Stuart A, Kalinowski J, de Andrade CRF. Randomized clinical trial: the use of SpeechEasy® in stuttering treatment. Int J Lang Commun Disord. 2016; 51(6): 769-74.

42. Saltuklaroglu T, Kalinowski J, Robbins M, Crawcour S, Bowers A. Comparisons of stuttering frequency during and after speech initiation in unaltered feedback, altered auditory feedback and choral speech conditions. Int J Lang Commun Disord. 2009; 44(6):1000-17.

43. Sparks G, Grant DE, Millay K, Walker-Batson D, Hynan LS. The effect of fast speech rate on stuttering frequency during delayed auditory feedback. J Fluency Disord. 2002; 27(3):187-201.

44. Stuart A, Kalinowski J. The perception of speech naturalness of post-therapeutic and altered auditory feedback speech of adults with mild and severe stuttering. Folia Phoniatr Logop. 2004; 56(6): 347-57.

45. Stuart A, Frazier C, Kalinowski J, Voss P. The effect of frequency altered feedback on stuttering duration and type. J Speech Lang Hear Res. 2008; 51: 889-97.

46. Unger JP, Glück CW, Cholewa J. Immediate effects of AAF devices on the characteristics of stuttering: a clinical analysis. J Fluency Disord. 2012; 37(2):122-34.

47. Verdurand M, Rossato S, Zmarich C. Coarticulatory Aspects of the Fluent Speech of French and Italian People Who Stutter Under Altered Auditory Feedback. Front Psychol. 2020; 11: 1745.

48. Arbabshirani N, Shafiei B, Marasi MR. Effects of Altered Auditory Feedback on Stuttering. Isfahan. Tese [Doutorado em Ciências Médicas] - Isfahan Universidade de Ciências Médicas; 2014.

49. Natke U, Grosser J, Kalveram KT. Fluency, fundamental frequency, and speech rate under frequency-shifted auditory feedback in stuttering and nonstuttering persons. J Fluency Disord. 2001; 26(3): 227-41.

50. Bray M, James S. An evaluation of a telephone assistive device (TAD) for people who stutter. Int J Speech Lang Pathol. 2009; 11(1): 54-60.

51. Buzzeti PBMDM, Oliveira CMCD. Immediate effect of delayed auditory feedback on stuttering-like disfluencies. Rev CEFAC. 2018; 20(3): 281-290.

52. Bothe AK, Davidow JH, Bramlett RE, Ingham RJ. Stuttering treatment research 1970–2005: I. Systematic review incorporating trial quality assessment of behavioral, cognitive, and related approaches. Am J Speech Lang Pathol. 2006; 15: 321–41.

Appendix 1 - Complete Search Strategies

In all databases the filter by year of publication was used, searching from 2000 and upwards. In databases where it was not possible to automatically use this filter (as in LILACS) articles published before this date were manually excluded by the main researcher.
The searches were performed on August 10, 2021.

CENTRAL

#1 MeSH descriptor: [Stuttering] explode all trees
#2 MeSH descriptor: [Speech Disorders] explode all trees
#3 (Stutter* OR Stammer* OR disfluenc* OR dysfluenc* OR fluency disorder* OR Adult Stutter* OR Childhood Stutter* OR "People who stutter"): ti,ab,kw (Word variations have been searched)
#4 #1 OR #2 OR #3
#5 MeSH descriptor: [Feedback, Sensory] explode all trees
#6 (auditory feedback OR altered auditory feedback OR Acoustic feedback OR acoustic-auditory OR delay* OR delayed auditory OR delayed auditory feedback OR second speech signal OR frequency altered feedback OR altered frequency OR Speecheasy):ti,ab,kw (Word variations have been searched)
#7 #5 OR #6
#8 #4 AND #7 Custom year range: 2000 - 2021

EMBASE (Acess by Periódicos Capes)

#4 #3 AND (2000:py OR 2001:py OR 2002:py OR 2003:py OR 2004:py OR 2005:py OR 2006:py OR 2007:py OR 2008:py OR 2009:py OR 2010:py OR 2011:py OR 2012:py OR 2013:py OR 2014:py OR 2015:py OR 2016:py OR 2017:py OR 2018:py OR 2019:py OR 2020:py OR 2021:py)
#3 #1 AND #2
#2 'auditory feedback'/exp OR 'acoustic feedback' OR 'audio feedback' OR 'auditory feedback' OR 'altered auditory feedback' OR 'delayed auditory feedback'/exp OR 'frequency altered feedback' OR 'altered frequency' OR speecheasy OR 'fluency devic*' OR 'digital speech aid' OR 'stuttering aid' OR 'telephone fluency system'
#1 'stuttering'/exp OR 'stutterer' OR 'stuttering' OR stutter* OR stammer* OR disfluen* OR dysfluen* OR 'fluen* speech' OR 'nonfluent speech' OR 'fluency disord' OR 'developmental stuttering'/exp OR 'adult stutt*' OR 'childhood stutt*' OR 'people who stutter' OR 'fluency disorder'/exp OR 'childhood-onset fluency disorder' OR 'dysfluency' OR 'fluency disorder' OR 'stammering'

MEDLINE (Acess by PubMed)

#1 "Stuttering"[MeSH Terms] OR "Speech Disorders"[MeSH Terms] OR "stutter*"[All Fields] OR "stammer*"[All Fields] OR "disfluenc*"[All Fields] OR "dysfluenc*"[All Fields] OR "fluency disorder*"[All Fields] OR "adult stutter*"[All Fields] OR "childhood stutter*"[All Fields] OR "People who stutter"[All Fields]
#2 "feedback, sensory"[MeSH Terms] OR "auditory feedback"[All Fields] OR "altered auditory feedback"[All Fields] OR "Acoustic feedback"[All Fields] OR "acoustic-auditory"[All Fields] OR "delay*"[All Fields] OR "delayed auditory"[All Fields] OR "delayed auditory feedback"[All Fields] OR "second speech signal"[All Fields] OR "frequency altered feedback"[All Fields] OR "altered frequency"[All Fields] OR "Speecheasy"[All Fields]
#3 #1 AND #2 AND (2000:2021[pdat])
(("Stuttering"[MeSH Terms] OR "Speech Disorders"[MeSH Terms] OR "stutter*"[All Fields] OR "stammer*"[All Fields] OR "disfluenc*"[All Fields] OR "dysfluenc*"[All Fields] OR "fluency disorder*"[All Fields] OR "adult stutter*"[All Fields] OR "childhood stutter*"[All Fields] OR "People who stutter"[All Fields]) AND ("feedback, sensory"[MeSH Terms] OR "auditory feedback"[All Fields] OR "altered auditory feedback"[All Fields] OR "Acoustic feedback"[All Fields] OR "acoustic-auditory"[All Fields] OR "delay*"[All Fields] OR "delayed auditory"[All Fields] OR "delayed auditory feedback"[All Fields] OR "second speech signal"[All Fields] OR "frequency altered feedback"[All Fields] OR "altered frequency"[All Fields] OR "Speecheasy"[All Fields])) AND (2000:2021[pdat])

LILACS (Acess by Periódicos Capes)

(Stutter$ OR Tartamud$ OR Gag$ or fluenc$ or disfl$) [Words] AND (auditory Feedback OR Retroalimentação auditiva or retroalimentación auditiva or audit$ or delay$ auditory feedback or frequency auditory feedback) [Words]

ClinicalTrials.gov

feedback, sensory OR auditory feedback OR altered auditory feedback OR Acoustic feedback OR acoustic-auditory OR delay* OR delayed auditory OR delayed auditory feedback OR second speech signal OR frequency altered feedback OR altered frequency OR Spe | Speech Disorders OR Stutter* OR Stammer* OR disfluenc* OR dysfluenc* OR fluency disorder* OR Adult Stutter* OR Childhood Stutter* OR "People who stutter"

WHO International Clinical Trials Registry Platform

"Stuttering" OR Stutter* OR Stammer* OR disfluenc* AND "auditory feedback" OR "altered auditory feedback" OR "delayed auditory" OR "delayed auditory feedback" OR "frequency altered feedback" OR "altered frequency" OR "Speecheasy"
Synonyms: stuttering; Has a stammer or stutter; Stammering; Stuttering, Familial Persistent 1; Stuttering in adolescence || auditory feedback; Altered auditory feedback; Delayed auditory feedback test || delayed auditory; Delayed auditory feedback test || delayed auditory feedback; Delayed auditory feedback test

OpenGrey

Various combinations of the terms used in the previous searches were tested, but any combination restricted the number of articles returned. In order to maintain sensitivity, two terms were searched separately:
search 1 Stutter*
search 2 Auditory Feedback

REHABDATA

Containing all of the words: Stuttering, containing at least one of the word(s): '"Devices" OR "auditory" OR "feedback" OR "delay*" OR "frequency" OR "Speecheasy" OR "Assistive" OR "technology