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Processing of Stuttered Speech by Fluent Listeners

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Abstract

Filled pause disfluencies (e.g., *uh*) elicit a disfluency bias in listeners: listeners predict that a speaker will name an unfamiliar object, versus a familiar one, when both are equally plausible referents. When listeners receive speaker-specific information indicating that disfluency is not reliably tied to word familiarity, the disfluency bias can be suspended. The first aim of this study was to determine if stuttered disfluencies would also elicit the disfluency bias in listeners. The second aim of this study was to determine if informing the listener that they will hear a speaker who stutters, would suspend the disfluency bias. Eye tracking data from 52 participants were analyzed using a 2 (acknowledgement) x 2 (target type) x 3 (fluency) mixed ANOVA. The dependent variable was the proportion of looks to the competitor object. The disfluency bias was found with typical and stuttered disfluencies when the target type was unfamiliar. Acknowledgement of stuttering did not suspend the bias.

Index Terms: stuttering, disfluency, language processing

1. Introduction

Stuttering is a speech disorder that is characterized by involuntary repetitions (e.g., *b-b-b-all*), prolongations of sounds (e.g., *ssssssssome*), and complete blockages (e.g., bl____ack) [1, 2]. It also involves disfluencies that occur in the speech of typically fluent speakers, such as filled pauses or interjections (e.g., *uh*, *um*, and *er*) [1, 2]. Typical filled pause disfluencies can affect the processing of language in several ways. For example, filled pauses such as *uh* can signal to the listener that a difficult word is coming or that the speaker is taking the time to plan and produce a more complex utterance [3-5]. However, beyond studies into recall and comprehension of stuttered speech [6-7], little is known about the degree to which stuttering affects the processing of language. Therefore, the first aim of this study was to determine if stuttering would have the same effect on listeners' processing of language as do typical disfluencies. Specifically, this study asked if the processing of stuttered speech would produce a *disfluency bias* in listeners.

The disfluency bias refers to a tendency in listeners to use the presence or absence of disfluencies in speech to make predictions about the familiarity or contextual probability of upcoming words. This bias was reported by Arnold, Hudson Kam, and Tanenhaus [3] in a visual world eye tracking study when verbal instructions contained the filled pause disfluency *thee uh* prior to target words (e.g., *Click on thee uh red flower*).

The experiment in Arnold et al. [3] used an array similar to that in Figure 1, and found that listeners looked more toward an unfamiliar, difficult to describe object (e.g., the symbols on the left side of Figure 1), rather than a familiar, easy to describe one (e.g., the scissors on the right side of Figure 1), when hearing the disfluency *thee uh*. Conversely, when participants heard a fluent instruction, they tended to look more towards a familiar object (e.g., the scissors in Figure 1). The term disfluency bias is used in the present study as it captures the listener's expectation of an unfamiliar word when disfluency is present, as well as the expectation of a familiar word when the speaker is fluent. The experiment in [3] contrasted images that were easy (e.g., flower) or difficult (e.g., circle with horns) to name. Naming difficulty was established in Arnold et al. [3] by having a group of participants rate the images on a scale from 1 (difficult to name) to 7 (easy to name); objects in the unfamiliar condition received ratings of 1.2 to 2.8 whereas all objects in the familiar condition received ratings of 7.

The disfluency bias can be suspended by providing listeners with certain information about the speaker's competency [3, 9]. This has included telling the listener that the speaker has object agnosia, so that familiar objects are difficult to describe [3]. In a different study, it involved telling the listener that the speaker was non-native, so the listener could infer that the speaker might have difficulty naming both high and low frequency objects [9]. In both cases, listeners received information about the speaker indicating that the disfluencies produced would not necessarily follow the expected patterns of occurrence.

A parallel can be drawn between the speaker competency information just described and *acknowledgement* of stuttering: a strategy in which individuals who stutter are encouraged to tell the listener that they stutter [10, 11]. Although research suggests individuals who use acknowledgement of stuttering are likely to derive some personal benefit from it [12], research into its effects on listeners has been limited to studies of perceived personality traits of people who stutter and offline recall and comprehension measures [13-15]. Thus, the second aim of this study was to investigate whether acknowledgement of stuttering would have an effect on language processing by suspending the expected disfluency bias.

The questions investigated in this study were twofold: would stuttered speech elicit the disfluency bias as do typical disfluencies, and would the disfluency bias be suspended when listeners were informed that they would hear a person who stutters. The research questions in this study were investigated using the visual world paradigm [16, 17],

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adapting the methodology and materials from Arnold et al. [3]. The visual world paradigm has been a valuable tool in the investigation of typical disfluency processing [3, 18-20] and provides a useful model to investigate the effects of stuttering, and acknowledgement of stuttering, on language processing.

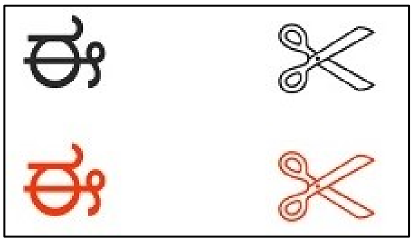

Figure 1: Sample visual stimuli

2. Methods

2.1. Design

A prospective two groups between by within-subjects design was used. Acknowledgement (acknowledgement, non-acknowledgement) was the between-groups factor. Target type (familiar, unfamiliar) and fluency (fluent, typically disfluent, and stuttered) were the within-groups factors. The dependent variable was logit transformed proportion of looks to the colour-matched competitor object, out of looks to all four depicted objects.

2.2. Participants

Sixty one participants were recruited from undergraduate linguistics courses and the general public. To be included in the study participants had be able to speak, read, and write English. Exclusion criteria included: colour-blindness, personal history of a communication disorder or having friends, family, or colleagues with such a history, and status as a student or professional in speech-language pathology or occupational therapy.

Linguistics students participated in exchange for course credits and members of the public received a $5 gift card. Data from a total of 52 participants were included in the analysis. Participants ranged in age from 18 to 72 years (M = 25.4 years, SD = 8.63) and reported an average of 16.7 years of education (SD = 3.12). Thirty five participants were female, and seventeen were male.

2.3. Materials and stimuli

Experimental stimuli consisted of auditory stimuli and visual arrays. There were 24 experimental trials and 24 filler trials. One trial consisted of one visual array presented with a verbal instruction to click on one of the images in the display (e.g., *click on the red scissors*).

2.3.1. Visual stimuli

Visual stimuli consisted of 24 experimental arrays and 24 filler arrays. The layout of the objects was replicated from Arnold et al. [3]. The experimental arrays consisted of two unfamiliar objects (e.g., circle with horns) on one side (i.e., left or right), two familiar objects (e.g., scissors) on the other side, with colour-matched objects horizontal to one another (e.g., the black scissors and circle with horns on top and the red scissors and circle with horns on the bottom). The objects within each pair of familiar and unfamiliar objects were shown in two different colours (e.g., black scissors and red scissors) to create a temporary ambiguity in the verbal instructions. The locations of the target and competitor objects were counter-balanced across the trials, so the target and competitor were positioned in different locations throughout the experiment.

The filler arrays consisted of pictures of four objects that were either all familiar or all unfamiliar. This was done to de-emphasize the familiar versus unfamiliar contrast of the experimental items. Consistent with the experimental arrays, each pair of objects was presented in two different colours (e.g., a red diamond and a blue diamond with a red car and a blue car).

The visual arrays were presented on a computer monitor with 1920 x 1080 screen resolution. Pictures of objects were presented on a white background, centered within each quadrant of the screen. A black fixation cross marked the center of each array. Pictures of experimental and filler objects were the same as those used in [3]. The familiar images originally come from a set of images standardized and normed for familiarity in [21]. Sets of objects for each array were provided by [22] as black line images and were coloured using GIMP 2.8.8 [23] photo editing software. Colours were chosen to be linguistically and visually distinct (e.g., red with black, but not black with blue).

2.3.2. Auditory stimuli

Auditory stimuli consisted of 24 experimental instructions and 24 filler instructions, one for each visual array. The verbal instruction in each trial directed participants to click on an object in the visual array (e.g., *click on the red flower*). Experimental and filler instructions each consisted of 8 fluent instructions, 8 typically disfluent instructions, and 8 stuttered instructions. Half of the items in each fluency condition instructed participants to click on a familiar target (e.g., *click on the purple car*), and half instructed them to click on an unfamiliar target (e.g., *click on the orange hill with dots on it*).

One fluent male speaker recorded the auditory stimuli, simulating typical and stuttered disfluencies. This speaker was capable of simulating the stuttered tokens to the satisfaction of a speech-language pathologist experienced in the diagnosis and treatment of stuttering. A male speaker was chosen because the majority of adults who stutter are male; the ratio in adulthood is 4 males to 1 female [1].

Fluent instructions asked participants to *click on the* [colour] [target object]. Instructions with typical disfluencies contained the disfluency *thee uh* prior to the colour word (e.g., *click on thee uh* [colour] [target object]). Instructions with stuttered disfluencies contained five iterations of a repeated syllable, two of which had elements of prolongation approximately 1.5 s in duration (e.g., *click on thththuh-th-thththuh-th-the* [colour] [target object]). The names used for each of the objects were the same as those used by Arnold et al. [3].

Each instruction in the list of verbal stimuli was recorded in its entirety and a single exemplar of the stem for the instructions in each fluency condition was chosen and cross-spliced onto the remainder of each instruction (i.e., the naming of the colour followed by the target object). That is, one exemplar of each of the following stems was chosen: *click on the*, *click on thee uh*, and *click on thththuh-th-thththuh-th-the*.

This procedure was followed to ensure that the stem of each item was consistent within each fluency condition.

2.3.3. *Equipment*

Auditory stimuli were recorded with a Shure SM58 microphone at a 44.1 kHz sampling rate and edited using Praat [24]. They were delivered to participants via external computer speakers. Data were collected using an EyeLink 1000 Plus desk-mounted eye tracker with a chin rest/head stabilizer [25]. It was used in monocular mode and set at a sampling rate of 1000 Hz. Stimuli were programmed for presentation using SR Research Experiment Builder [26]. Participants followed experimental instructions using a mouse connected to the computer.

2.4. Procedure

2.4.1. *Orientation and equipment set-up*

After orientation to the task, participants provided informed consent and completed a screening questionnaire, confirming inclusion and exclusion criteria. A nine point calibration was used for the eye-tracker. Calibration was repeated following any breaks or if a drift check indicated that it was necessary.

2.4.2. *Experimental task*

Three practice trials were followed by 24 experimental trials and 24 filler trials presented in randomized order with a scheduled break halfway between. The experiment started after verbal directions were given. In the acknowledgement group, participants read the following information on the computer screen, after the practice trials, but before the experimental and filler trials:

> The speaker that you will hear is a person who stutters. Stuttering occurs in different manners for different people and it may occur at any time. Stuttering is not associated with specific personal characteristics and can occur with both easy and difficult words. The speaker has been receiving treatment for stuttering.

Each trial started with a drift check, after which participants viewed the array for an unconstrained period of time prior to presentation of the auditory stimuli. This step was taken to reduce the potential for an inherent novelty bias [22]. Participants then clicked on the centre of the screen to trigger the auditory stimulus, ensuring that they started each trial fixating on a consistent and neutral point. When participants clicked on the fixation cross to trigger presentation of the auditory stimuli, they heard an instruction to click on one of the four objects. After they made their selection, the next trial began. When all the trials were completed, participants were then debriefed about the true purpose of the study.

The experimental task and procedures for each group were the same, with the exception of the acknowledgement manipulation. In the non-acknowledgement group, participants were not presented with a screen providing information about the speaker at the beginning of the experiment. However, they were presented with the same information at the end of the study, as part of the debriefing procedure.

2.4.3. *Data pre-processing and analysis*

Sample reports were obtained from EyeLink Data Viewer [27] for the acknowledgement and non-acknowledgement groups, using a time window of 2500 ms, beginning at 500 ms prior to the onset of the colour word (e.g., at the onset of *red* in *click on the red*…). A sample refers to an individual observation, indicating the location of the gaze on the computer screen, in this case recorded 1000 times per second. Data were formatted using R 3.2.0 [28] and a Python 2.4.4 script available from SR Research [29]. The script was used to bin the data into 20 ms intervals and calculate the proportion of samples (i.e., looks) located in each of the four image areas for each 20 ms interval. Data were subjected to the empirical logit transformation [30]. With the exception of Figure 2, proportion of looks in the data analysis and results sections refers to transformed proportion of looks. All data were analyzed from 200 ms to 1000 ms following the onset of the colour word. It takes approximately 200 ms to program and launch a saccade (i.e., an eye movement to look at an object), so effects are not expected to be present until this point [31].

Data were analyzed using a 2x2x3 mixed ANOVA with between-groups factors of acknowledgement (acknowledgement, non-acknowledgement) and within-groups factors of target type (familiar, unfamiliar) and fluency (fluent, typically disfluent, stuttered). The dependent variable was the transformed proportion of looks to the competitor object out of looks to all four objects. The competitor object is the object that matches in colour with the target object. It is the competitor because, during the period of temporary ambiguity before the target is actually named, it is in direct competition with the target object as a potential referent of the experimental instruction. Significant effects were followed up with post-hoc tests, using Fisher's least significant difference (LSD) procedure, as no factor had more than three levels [32]. When assumptions of sphericity were violated, as indicated by a significant Mauchly's test [33], degrees of freedom were corrected using the Huynh-Feldt Epsilon [34].

3. Results

At the outset of this study, it was hypothesized that typical filled pause disfluencies and stuttered disfluencies would elicit the disfluency bias in listeners; results provided support for these hypotheses. It was also hypothesized that acknowledgement of stuttering would suspend the disfluency bias; results did not support this hypothesis.

Homogeneity of variance was verified using Levene's test [35]. The dependent variable was checked for normality by inspection of normal Q-Q plots. Mauchly's test [33] indicated that the assumption of sphericity had not been violated for fluency ($\chi^2(2) = .081$, $p = .96$, *ns*), or for fluency by target type ($\chi^2(2) = 2.30$, $p = .32$, *ns*). Results indicated a significant main effect of fluency ($F(2,100) = 5.30$, $p = .007$, $\eta_p^2 = .096$). The fluency by target type interaction was also significant ($F(2,100) = 3.42$, $p = .037$, $\eta_p^2 = .064$). All other main effects and interactions did not reach significance.

Regarding the main effect of fluency, pairwise comparisons revealed that regardless of target type, the proportion of looks to the competitor object was greater when the instruction was fluent compared to when it was typically disfluent ($p = .003$) or when it was stuttered ($p = .036$), likely due to the strong competition effect observed from the familiar object in the fluent/unfamiliar condition.

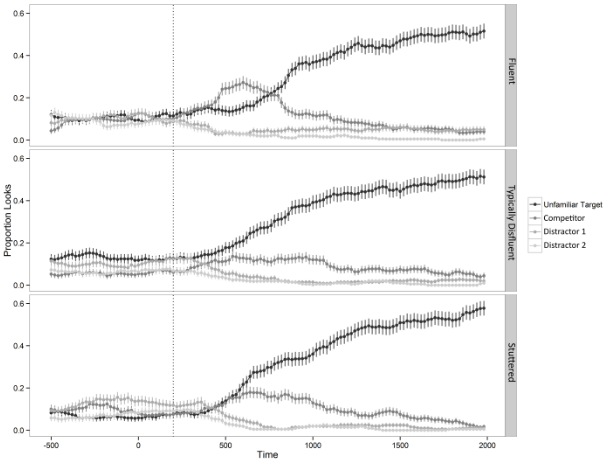

Figure 2: *Grand average proportion of looks when target type is unfamiliar collapsed across acknowledgement groups.*

In the case of the significant fluency by target type interaction, follow-up analysis was conducted via simple effects ANOVAs at each level of target type which were in turn followed by Fisher's LSD procedure when *F* was significant [36]. There was no significant simple effect of fluency when the target type was the familiar object ($F(2,102) = .096$, $p = .91$, *ns*, $\eta_p^2 = .002$). However, when the target type was the unfamiliar object, there was a significant simple effect of fluency ($F(2,102) = 9.80$, $p <. 001$, $\eta_p^2 = .16$). Pairwise comparisons revealed that the proportion of looks to the familiar competitor object in the fluent condition was greater than in both the typically disfluent ($p < .001$) and stuttered ($p = .005$) conditions. This is likely due to the strong competition effect observable in Figure 2 (top panel). The difference between the typically disfluent and stuttered conditions was not significant ($p = .14$, *ns*).

4. Discussion

The aim of this study was to explore the hypotheses that: 1) Typical filled pause disfluencies would elicit the disfluency bias; 2) Stuttered disfluencies would elicit the disfluency bias; and 3) Acknowledgement of stuttering would suspend the disfluency bias for typical and stuttered disfluencies. Findings supported the hypotheses that typical and stuttered disfluencies would elicit the disfluency bias, but did not support the hypothesis that the disfluency bias would be suspended via acknowledgement of stuttering.

4.1. Typical and stuttered disfluencies

It was hypothesized at the outset of this study that typical and stuttered disfluencies would elicit the disfluency bias in listeners when resolving a temporary ambiguity in the visual world paradigm. Findings provided support for these hypotheses. The presence of disfluency did have statistically significant effects on competitor looks when an unfamiliar target was named.

The disfluency bias was observed in the pairwise comparisons for the fluent versus typically disfluent ($p < .001$) and the fluent versus stuttered ($p = .005$) instructions when the target type was unfamiliar. There were fewer looks to the familiar object in the typically disfluent and stuttered conditions, relative to the fluent condition. In other words, the presence of typical or stuttered disfluencies reduced listeners' expectation for the speaker to name a familiar object. The pairwise comparisons of typically disfluent versus stuttered instructions were not significant ($p = 0.14$, *ns*), indicating that looks to familiar objects were similarly reduced in both disfluent conditions.

Typical disfluencies may make unpredictable words easier to process [37], and thus have the potential to facilitate speech processing. Disfluencies can be an informative component to the speech signal when they occur in a pattern that is consistent with listener expectations of discourse new [19-20], low frequency [4, 9], contextually improbable [4, 37], or unfamiliar words [3].

Prior to this study the degree to which stuttering affected language processing was completely unknown. The findings in this study suggest that stuttered disfluencies that share similarities with typical disfluencies may not be problematic; the occurrence of the disfluency bias suggests that stuttered disfluencies may not interfere with reference resolution for the listener and could even facilitate it in certain contexts. Although tokens of stuttered disfluency in this study were designed to be distinctly recognizable as stuttered speech, they shared similarities with the tokens of typical disfluency to facilitate comparison across experimental conditions.

Stuttered disfluencies occur in patterns similar to typical disfluencies [38-40], as well as in patterns and contexts that differ [41-43]. It seems unlikely that stuttered disfluencies could be expected to consistently have the same effects on language processing as do typical disfluencies. This could be investigated by further manipulating the type and severity of stuttered disfluencies, as well as comparing the effects of stuttered disfluencies when they are and are not consistent with the patterns of typical disfluencies. Exposing participants to either typical or stuttered disfluencies, rather than both types, may also affect findings. Finally, listeners may process typical and stuttered disfluencies differently when they occur in more natural contexts during conversational speech.

4.2. Acknowledgement of stuttering

Acknowledgement of stuttering was not found to suspend the disfluency bias. Listeners can rapidly adapt to speaker-specific patterns in order to facilitate language processing [44]. In this study, listeners may have adjusted their expectations rapidly after hearing tokens of stuttering. Such rapid adaptation may have made the acknowledgement of stuttering superfluous, as far as language processing is concerned.

5. Conclusions

Listeners responded to stuttered disfluencies in a manner similar to typical disfluencies, but were not affected by the acknowledgement. Further investigation is warranted to better describe the effects of stuttering on speech processing and mitigating factors. Based on the current results, there is no evidence that acknowledgement of stuttering facilitates or influences language processing in the listener. Acknowledgement of stuttering still holds value as a coping mechanism for people who stutter.

6. Acknowledgements

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