Speech fluency in bilinguals who stutter: Language proficiency and attentional demands as mediating factors

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Abstract

Purpose: The current study examines how speech disfluencies manifest themselves in the two languages of bilingual persons who stutter, starting from the hypothesis that stuttering is associated with an attentional deficit at the level of speech production.

Methods: Twenty-eight bilingual people who stutter performed a spontaneous and a controlled speech production task, once in their dominant and once in their non-dominant language. The controlled production task (i.e. a network description task) was carried out once under a full-attention condition and once under a divided-attention condition where a non-linguistic, pitch discrimination task was performed simultaneously.

Results: In both the spontaneous and the controlled speech task, bilingual persons who stutter produced more (typical and stuttering-like) disfluencies in their L2 than in their L1. Furthermore, whereas the typical disfluencies increased when attention was directed away from speech production, stuttering-like disfluencies decreased. This effect was however restricted to L2. In addition, L2 proficiency was generally found to be a predicting factor, with higher proficiency leading to fewer disfluencies.

Conclusions: These results suggest that speaking in a non-dominant language increases both typical and stuttering-like disfluencies in bilingual persons who stutter, but also that these two types of dysfluencies differ regarding their attentional origins. Our findings offer further support for attentional accounts of stuttering and have both theoretical and clinical implications.

Keywords: stuttering, bilingualism, language control, attention, proficiency

1. Introduction

Stuttering is a disorder in which speech is characterised by atypical or stuttering-like disfluencies, such as sound/syllable repetitions (e.g. 'mo-mo-mother'), prolongations (e.g. 'mmmother'), and the inability to initiate sounds (blocks; e.g. 'm-----mother') (e.g. Yairi, 2007). These stuttering-like disfluencies should be distinguished from typical disfluencies, which constitute a natural property of human speech and include silent pauses (e.g. 'the door is [pause] open'), filled pauses (e.g. 'the door is *uhm* open'), and word repetitions (e.g. 'the door *door* is open') (Tumanova, Conture, Lambert, & Walden, 2014). Stuttering is a reasonably frequent speech disorder, affecting approximately 1% of the adult population worldwide (Buchel & Sommer, 2004). Its most common form is referred to as developmental stuttering, and usually evolves around the age of two to five without being linked to any apparent brain damage or other known cause. Research on stuttering tends to focus on monolingual speech, whereas a considerable number of persons who stutter (PWS) potentially speak more than one language due to a surge in bilingualism (i.e. over 50% of the world population now speaks more than one language; Grosjean, 1998). Remarkably, studies on the relationship between stuttering and bilingualism are quite scarce (Van Borsel, 2011) and the current study's aim is therefore to shed light on of how stuttering manifests itself in the two languages of bilingual PWS.

1.1 The supposed underlying origin of stuttering

Speech fluency is regarded as an automatic procedural skill (Schmidt, 1992), which implies that little attention and effort is needed to produce fluent utterances. Yet, all spontaneous speech is characterised by frequent occurrences of disfluencies, caused by difficulties during speech planning, such as word retrieval (Shriberg, 2001). Contrary to these typical disfluencies, the cause of stuttering-like disfluencies is still a topic of scientific debate, but it is likely multifactorial. Factors that have been suggested include genetics, motor control skills, environment, temperament, and linguistic factors (Conture & Curlee, 2007; Smith & Weber, 2017).

Within the psycholinguistic perspective, a great deal of research has focused on speech planning. For instance, Kolk and Postma (1997) provided their covert repair hypothesis (CRH) based on Levelt's (1983) model of speech production and monitoring. Speech monitoring is the process of inspecting and correcting speech errors that operates before (i.e. inner speech), during, as well as after articulation (Hartsuiker & Kolk, 2001; Postma, 2000). The CRH postulates that stuttering-like disfluencies arise from an underlying deficit in phonetic encoding, requiring covert (prearticulatory) repairs of planned speech, which in turn have an effect on ongoing articulated speech, leading to disfluencies. Yet, according to Howell and Au-Yeung's (2002) EXPLAN account, fluency failures appear when speech planning (PLAN) is not completed in time for speech execution (EX). The model assumes that PLAN and EX take place in parallel and are independent of each other. This independence allows a current word to be executed, while the plan of a subsequent word is being generated. Especially phonetically difficult words will increase planning time and lead to either hesitations on or repetitions of the preceding (function) word (i.e. stalling), or repeated execution of the part of the word that was already planned (i.e. advancing). The EXPLAN account therefore assumes that motor levels are as important as the linguistic planning levels in leading to fluency failure, and mainly their interaction may lead to these failures (Howell, 2004). It also stresses that failures are not errors (as proposed by the CRH) and do not involve a monitoring process.

Another stuttering account that does propose the involvement of monitoring processes is the Vicious Circle Hypothesis (VCH; Vasiç & Wijnen, 2005). According to this theory, PWS invest a disproportionally large amount of their attentional resources in speech monitoring, rendering this process hypersensitive. That is, the speech monitor of PWS is too alert and detects the smallest deviations typically not detected by people who do not stutter (PWNS) (Vasiç & Wijnen, 2005). The attempts of the hypersensitive speech monitor to correct the high proportion of detected mistakes then paradoxically result in the production of stuttering-like disfluencies. In line with this hypothesis, it has been found that PWS judge utterances of both

PWS and PWNS as more disfluent relative to judgments of PWNS (Lickley, Hartsuiker, Corley, Russell, & Nelson, 2005). A key prediction of the VCH is that the (hyper)sensitivity of the speech monitor varies as a function of the available attention for this process. Reducing the amount of attention that can be invested in speech monitoring, for instance by asking PWS to divide their attention between speaking and a secondary task, should thus decrease their stuttering rate. This theory has also been proposed in other domains, such as motor learning. It seems that deliberate attempts to control motor skills interfere with performance and even cause performance breakdown. In contrast, when attention is directed toward an unrelated task, movement accuracy and efficiency increase (Beilock, Carr, MacMahon, & Starkes, 2002). Wulf and Lewthwaite (2016) formalised these findings in their Optimizing Performance through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory.

1.2 Stuttering and attentional demands

Although the VCH predicts that redirecting attentional resources to a task other than speaking should benefit PWS, empirical findings on stuttering under conditions of divided attention are inconsistent. Whereas some studies demonstrate a decrease in stuttering frequency (e.g. Arends, Povel, & Kolk, 1988; Eichorn, Marton, Schwartz, Melara, & Pirutinsky, 2016; Eichorn, Pirutinsky, & Marton, 2019; Vasiç & Wijnen, 2005), others have found an increase (e.g. Bosshardt, 2002; Caruso, Chodzko-Zajko, Bidinger, & Sommers, 1994). Metten et al. (2011) unified these seemingly discrepant outcomes by arguing that the effect of dividing attention depends on the nature of the secondary task. Specifically, linguistic secondary tasks (e.g. phoneme monitoring) seem to elevate the frequency of stuttering-like disfluencies, whereas non-linguistic tasks (e.g. working memory taxation) appear to lower the frequency. Conceivably, non-linguistic tasks may draw attention away from speech monitoring, whereas linguistic tasks may draw more attention toward speech monitoring. Whether similar effects of secondary tasks may be found for typical disfluencies is not yet clear. The few studies on this topic were carried out on PWNS (e.g. Cook & Meyer, 2008; Ferreira & Pashler, 2002;

Hartsuiker & Barkhuysen, 2006; Oomen & Postma, 2002; Roelofs, 2008). Still, the general finding is that frequency of typical disfluencies in PWNS increases under conditions of divided attention, regardless of the nature of the secondary task. Thus, the effects of attentional load seem to interact with the nature of speech disfluency.

Interestingly, Poarch and Bialystok (2015) recently proposed that bilingualism may be considered as a form of linguistic dual-tasking, in which attention has to be divided between two linguistic tasks. The primary task would be speaking and the secondary task is language control. Indeed, numerous studies have demonstrated that the two languages of bilinguals are always simultaneously activated to some extent (e.g., Costa & Santesteban, 2004; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Van Assche, Duyck, & Gollan, 2013; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009), and therefore require an active language control system that inhibits the inappropriate language and selects the appropriate one (Green, 1998). Inhibition is especially required in bilinguals with a less proficient second language (L2) who need to suppress the dominant first language (L1) (Costa & Santesteban, 2004; Meuter & Allport, 1999). For these unbalanced bilinguals, attentional demands should be higher when speaking in L2 as opposed to L1 (Kormos, 2006). Given the supposed detrimental effect of linguistic secondary tasks on stuttering rate in PWS, the very interesting question arises whether the (linguistic) language control demands implied by bilingualism somehow influence manifestation of stuttering-like disfluencies.

1.3 Speech fluency in bilingual PWS

Possible quantitative differences in speech disfluencies among monolingual and bilingual populations are still a matter of debate. Some studies claim increased stuttering prevalence in bilinguals (e.g. Howell, Davis, & Williams, 2009; Stern, 1948; Travis, Johnson, & Shover, 1937) whereas others found no difference at all (e.g. Au-Yeung, Howell, Davis, Charles, & Sackin, 2001). In addition, speech fluency in the two languages of bilingual PWS may not be equal. Indeed, even in normal speech, L2 utterances are more susceptible to typical disfluencies as opposed to L1 utterances (e.g. Van Hest, 1996; Wiese, 1984). According to the VCH account, unbalanced bilingual PWS should also experience more stuttering-like disfluencies in their less proficient L2, especially if language control is a linguistic secondary task that directs an increasing amount of attention toward speech monitoring. In fact, when Lim, Lincoln, Yiong, and Onslow (2008) tested both balanced and unbalanced English-Mandarin PWS, they observed more stuttering-like disfluencies in the non-dominant language of unbalanced bilinguals compared to their dominant language. These were however merely descriptive comparisons and the statistical reliability of said differences was not tested. Still, a similar observation was made by Maruthy, Raj, Geetha, and Priya (2015), but these authors also noted more disfluencies for content words (e.g. verbs and nouns) in L1 compared to L2, as opposed to more disfluencies for function words (e.g. articles, prepositions, and conjunctions) in L2 compared to L1. Schäfer and Robb (2012) reported similar word type patterns in their L1-dominant German-English bilinguals without establishing differences between L1 and L2 in overall stuttering frequency. Additionally, case studies have presented mixed results, with some describing increased stuttering in the more proficient language (Carias & Ingram, 2006; Howell et al., 2004) and others in the less proficient language (Ardila, Ramos, & Barrocas, 2011).

There are two potential explanations for these inconsistent findings. First, the bilingual PWS may have differed in L2 proficiency across studies. As we could see in, for instance, the study by Lim et al. (2008), there only seems to be a difference in fluency between languages for unbalanced bilinguals, who are not equally fluent/proficient in both languages. If studies fail to make this distinction by not testing or controlling for language proficiency, this would affect results. Second, prior work generally made no or ill-defined distinctions between typical and stuttering-like disfluencies (for a more detailed discussion, see Howell et al., 2004 and Roberts, 2011), so it is not clear whether bilingual PWS are generally more disfluent in their less proficient language, or whether they are actually stuttering more severely in that language. Not distinguishing between typical and stuttering-like disfluencies may mask crucial influences of employing two languages that exclusively apply to stuttering-like disfluencies, because these two disfluency types may have a different origin.

Overview of the current study's aims

The present work set out to examine whether stuttering manifests itself differentially in L1 versus L2 speech of bilingual PWS (Aim 1), making it the first systematic group study to compare stuttering disfluency in bilinguals' two languages. We distinguished between typical disfluencies (i.e. silent pauses, filled pauses, and word repetitions) and stuttering-like disfluencies (i.e. sound/syllable repetitions, prolongations, and blocks). This categorisation was based on accepted distinctions for typical disfluencies within speech monitoring research in PWNS (Declerck & Kormos, 2012; Oomen & Postma, 2001) and for stuttering-like disfluencies within the stuttering literature (Yairi, 2007). Because stuttering rates may depend on the speaking task (Van Borsel, 2011), we assessed L1 and L2 speech fluency of bilingual PWS using both a spontaneous speaking task and a controlled network description task. Under the assumption that L2 speech requires language control (cf. Poarch & Bialystok, 2015) that may be considered as a linguistic dual task, and given that such tasks increase stuttering in monolingual PWS (Metten et al., 2011), we predicted an increase in both stuttering-like (Hypothesis 1.1) and typical (Hypothesis 1.2) disfluencies in L2, relative to L1 speech. This may interact with L2 proficiency, with higher proficiency creating lower demands and thus, fewer stuttering-like (Hypothesis 1.3) and typical (Hypothesis 1.4) disfluencies. Additionally, as previous research has found that stuttering-like disfluencies are higher in L2 mainly for function words, we also made the distinction between word types in the categorisation of speech disfluencies in the spontaneous speech task (Hypothesis 1.5).

An additional goal of the current study was to test whether a non-linguistic secondary task differentially affects speech fluency in the two languages of bilingual PWS (Aim 2). Based on the view that stuttering-like disfluencies are caused by a hypersensitive speech-monitor, we assumed an overall decrease in stuttering when attention is divided between speech and a secondary non-linguistic task (Hypothesis 2.1). This contrasts with typical disfluencies, which we expected to increase under conditions of divided attention (Hypothesis 2.2), as these may be caused by difficulties during speech planning. Part of the description task was therefore presented together with the non-linguistic secondary task. Under these circumstances, we generally predicted fewer stuttering-like disfluencies and more typical disfluencies. In addition, the dual task effect supposedly becomes larger with stuttering severity, due to a more sensitive speech monitor. Analogous, if L2 speech is indeed more prone to both typical and stuttering-like disfluencies, L2 fluency should benefit more than L1 speech under conditions of divided attention for stuttering disfluencies, (Hypothesis 2.3), but L2 speech may actually be hampered more by a non-linguistic secondary task than L1 speech for typical speech errors (Hypothesis 2.4). Again, L2 proficiency may play a mediating role (Hypothesis 2.5).

2. Methods

2.1 Participants

Twenty-eight adult PWS (19 men), aged 19-53 years, were recruited from a stutter treatment centre in Flanders (Belgium; BVBA Algemene Aanpak Stotteren) and received a €25 participation fee. The sample size was based on the opportunity to recruit as many adult PWS as possible within a time frame of one year. Participants reported childhood onset of stuttering and received speech therapy in their L1, Dutch. They reported having no other language, voice, hearing, or neurological problems. Informed consent was obtained at the beginning of testing under a protocol approved by the ethical committee of the Psychological Sciences Research Institute (Université Catholique de Louvain, Belgium). All participants were Dutch-French (N = 7) or Dutch-English (N = 21) bilingual PWS. Our sample did not contain monolinguals, as the aim of this study was not to look at the effect of bilingualism on stuttering but rather to examine how stuttering manifests itself in the two languages of bilingual PWS.

To assess language proficiency, participants filled in the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007), in which they were asked to score themselves on oral production and comprehension as well as reading on an 11-point Likert scale (0 = no proficiency, 10 = full proficiency). In addition, the vocabulary test LexTALE (Lemhöfer & Broersma, 2012) was administered as an objective measure of L1 and L2 proficiency. Participants were asked to indicate their most dominant (proficient) language as their L1, which in this case was always their native one. Participants self-assessed the level of exposure to both languages by indicating in what percentage of their time was spent speaking in L1 and L2. To obtain a subjective estimate of stuttering severity in each language, participants completed the Overall Assessment of Stuttering Experience Survey (OASES; Yaruss & Quesal, 2006) for both languages, of which the score reflects the degree of adverse impact a speaker experiences due to stuttering. It entails, among other things, the functional communication difficulties a speaker may have in different speaking environments and the impact of stuttering on the speaker's overall quality of life. OASES yields scores on 5-point scales, with higher scores indicating higher levels of negative impact. Participants also produced three minutes of spontaneous speech, which was then analysed for stuttering-like disfluencies. Demographic data are reported in Table 1. Paired sample *t*-tests showed that the bilingual PWS were more proficient in L1 than in L2 for all proficiency measures. They also used their L1 more frequently and reported to suffer more from stuttering in their L2 than in their L1.

< INSERT TABLE 1 ABOUT HERE >

2.2 Materials and procedure

All participants were tested individually and completed both the spontaneous speaking and network description task once in L1 and once in L2, in two separate sessions. During each session, all communication between the experimenter and the participant was in the session's target language. The order of the sessions and the tasks within each session (i.e. LEAP-Q, LexTALE, OASES, spontaneous speaking, and network description task) were counterbalanced across participants.

2.2.1 Spontaneous speaking task

In the spontaneous speaking task, participants were asked to produce continuous speech in both languages over a one-minute period for each of the following topics: (1) What do you do in the morning when you get up?; (2) Provide a description of your home; (3) What do you do in your spare time? The order of the different topics as well as language order were counterbalanced across participants.

2.2.2 Network description task

Primary task. The network description task was adapted from previous studies (Declerck & Kormos, 2012; Hartsuiker & Notebaert, 2010; Oomen & Postma, 2002). On each trial, a network was presented that contained eight drawings connected with one, two, or three straight or curved lines. Participants were instructed to describe the path of a dot that moved over the network at a fixed pace. The fixed pace was used to avoid that PWS would use strategies to reduce stuttering, such as slowing down speaking rate. The dot completed the network in 43s (Dutch) or 55s (French/English), which was piloted as being a normal speaking rate for PWNS, and this was also used in previous studies (Declerck & Kormos, 2012; Hartsuiker & Notebaert, 2010). We instructed participants to use full sentences that contained the direction (left, right, up, or down), the position of the line (upper, lower, left, or right), the shape of the line (curve, straight line, or diagonal line), and the next object. An example of a correct sentence would be «*The ball goes from the bucket to the right by taking the straight line to the handcuffs*» (see Figure 1).

< INSERT FIGURE 1 ABOUT HERE >

Participants carried out 20 network trials in each language, ten in the full-attention and ten in the divided-attention condition. To create the different trials, 40 monochrome drawings of highly frequent words were selected (Severens, Van Lommel, Ratinckx, & Hartsuiker, 2005). Words were matched across Dutch, French, and English for word length and frequency using WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004). Each drawing was presented four times, twice in each condition. In addition, 20 different configurations were created, which refer to the way the drawings are connected through the lines. To ensure that the full- and divided-attention conditions were as similar as possible in terms of description difficulty, the same set of drawings was presented once in each condition, but in a different configuration. Furthermore, each configuration was presented once in each language (but with a different set of drawings) to maximise description similarity across languages. Finally, the configurations that were used in the L1 full-attention condition were used for the L2 divided-attention condition of each participant and vice versa. All networks were programmed and presented using Java.

To ensure that the names of the images were known and that the instructions were clearly understood, the task started with a familiarisation phase, where the images were presented with their corresponding names, followed by a pre-recorded description of a trial. Each condition then contained one practice and ten randomly presented experimental trials. The order of the conditions was counterbalanced across participants. When necessary, feedback was given by the experimenter (e.g. when the participant tended to not produce full sentences).

Secondary task. In the divided-attention condition, participants were asked to perform a pitch discrimination task simultaneously with the network description task. They discriminated between tones with a frequency of 262 Hz (low tone) and 524 Hz (high tone) by pressing a left (A) or right button (P) on an AZERTY keyboard. Tones were presented via E-prime 2.0 through an external speaker and lasted 200 ms. The inter-trial interval was randomised to increase the attentional demands of this task and lasted either 900 or 1500ms (see Szmalec, Vandierendonck, & Kemps, 2005). Participants each received 32 practice trials before the task began in combination with the network description task.

3. Results

3.1 Speech production pre-processing

For both production tasks, the speech output was recorded, and afterwards transcribed and coded by one of the authors. Transcriptions contained an orthographic rendition of the participant's speech output, interspersed with a code for any disfluency. The coding scheme included typical disfluencies (i.e. silent pauses, filled pauses, and word repetitions) and stuttering-like disfluencies (i.e. sound/syllable repetitions, prolongations, and blocks). Regardless of the number of stuttering-like disfluencies occurring on a single word, only one stuttering moment was counted for each word stuttered. The raw numbers of each disfluency type (typical and stuttering-like) for each trial were converted into proportion scores by calculating the proportion of disfluencies over the total number of produced words for each trial (i.e. one-minute speech in the spontaneous speaking task and a network in the network description task, respectively). For the spontaneous speaking task, one L2 recording was excluded from analyses due to technical problems (1.19% of the data). For the network description task, the speech of five L1 trials (0.89%) and four L2 trials (0.71%) had to be excluded due to a technical fault. A second rater with Dutch as L1 and high proficiency in both English and French assessed 5% of all data to evaluate reliability of the transcriptions. The convergence between the two raters was 92.61% for spontaneous speech and 90.22% for network description. Given this high convergence, the transcriptions of the first rater were considered as reliable.

3.2 Spontaneous speaking task

To address whether stuttering manifests itself differentially in the L1 and the L2 of bilingual PWS (Aim 1), we fitted generalised linear mixed-effects models on proportions of disfluency with maximum likelihood estimates using the *glmer* function from the *lme4* package in R (Bates, Mächler, Bolker, & Walker, 2015). This was done separately for stuttering-like

(Hypothesis 1.1) and typical (Hypothesis 1.2) disfluency. In the first model, Language (L1 and L2) was entered as fixed effect, and random effects were intercepts for Participant and Trial (i.e. one-minute speech). The second model also included by-Participant random slopes for Language, because maximum likelihood estimations justified their inclusion. Our third and final model additionally included by-Trial random slopes for Language, but was not a good fit (see Appendix). We therefore kept and report the second model for both types of disfluency. Mean proportions of stuttering-like and typical disfluencies for each Language (L1 and L2) are summarised in Table 2. We then analysed whether L2 proficiency predicted the proportion of stuttering-like (Hypothesis 1.3) and typical (Hypothesis 1.4) disfluency. We conducted multiple linear regressions with the scores of the L2 LexTALE; the LEAP-Q scores for L2 production, L2 comprehension, and L2 reading; and L2 exposure. In addition, we analysed the number of stuttering-like disfluencies while distinguishing for Word Type (Function vs. Content), using the number of stuttering events per individual as a proportion of all words produced by that individual (M_{Function} = 0.04, SD = 0.09; M_{Content} = 0.07, SD = 0.10). We employed a linear regression model with Language and Word Type as fixed effect, and intercepts for Participant and Trial. Our second and final model also included by-Participant random slopes for Language, because maximum likelihood estimations justified their inclusion.

Stuttering-like disfluency. The modelling on stuttering-like disfluencies revealed a significant main effect of Language, $\chi^2(1) = 20.93$, $p < .001$, indicating more stuttering-like disfluencies in L2. Regarding language proficiency, multiple regressions returned a significant model ($F(5,77) = 2.169$, $p = .066$, $R^2 = .123$, Adjusted $R^2 = 0.067$), where L2 LexTALE performance came out as a significant predictor ($r^2 = -.005$, $p = .022$), with higher LexTALE scores predicting fewer disfluencies.

Typical disfluency. The modelling on the proportion of typical disfluencies showed a significant main effect of Language, $\chi^2(1) = 40.28$, $p < .001$, also indicating more typical disfluencies in L2. Conducting multiple regressions on language proficiency, a significant regression equation was found ($F(5,243) = 2.665$, $p = .023$, $R^2 = .052$, Adjusted $R^2 = .032$), with L2 LexTALE as a significant predictor ($r^2 = -.001$, $p = .009$). Again, higher LexTALE scores predicted fewer disfluencies.

Function vs. content. The modelling on the number of stuttering-like disfluencies for function and content words, returned a significant main effect of Word Type ($t(300.2)) = 2.860$, $p = .005$), with more disfluency on content words ($M = 7.15\%$, $SD = 10.40\%$) than on function words ($M = 4.36\%$, $SD = 8.76\%$). Of course, the main effect of Language was again present ($t(36.97)) = 2.632$, $p = .012$), with more disfluency in L2. There was, however, no interaction between Language and Word Type.

< INSERT TABLE 2 ABOUT HERE >

3.3 Network description task

3.3.1 Speech fluency

As for spontaneous speech, generalised linear-mixed effects modelling was carried out with maximum likelihood estimations on the proportion of each disfluency type, separately for stuttering-like and typical disfluencies. To address whether stuttering manifests itself differentially in the L1 and the L2 of bilingual PWS (Aim 1) and whether a non-linguistic secondary task differentially affects stuttering-like versus typical disfluencies in bilingual PWS (Aim 2), we entered Language (L1 and L2) as well as Attention (full and divided) as fixed effects, and their interactions. We additionally included Stuttering Severity (i.e. mean proportion of stuttering-like disfluencies during three minutes of spontaneous speech in the L1), as previous research suggests that stuttering severity may interact with Attention. As random effects, we had intercepts for Participant and Trial in our first model. In our second model, we additionally included by-Participant random slopes for Language, and in our third also for Attention, because maximum likelihood estimations justified this inclusion. The fourth model also contained by-Trial random slopes for Language, but did not provide a good fit (see Appendix). We report the results of the third model. Planned comparisons were carried out via the lsmeans R-package (Lenth, 2016). Mean proportions of stuttering-like and typical disfluencies for each level of Attention (full and divided) and Language (L1 and L2) of the network description task are shown in Table 2. Again, we subsequently performed multiple linear regressions (similar to 3.2) to test whether L2 language proficiency predicted the proportion of typical and stuttering-like disfluencies under full or divided attention.

Stuttering-like disfluency. The modelling on stuttering-like disfluencies revealed a main effect of Language ($\chi^2(1) = 14.479$, $p < .001$), indicating more disfluencies in L2 (Hypothesis 1.1). There was also a main effect of Attention ($\chi^2(1) = 5.053$, $p = .025$), with decreased disfluency in the divided attention condition (Hypothesis 2.1). The main effect of Stuttering Severity was also significant ($\chi^2(1) = 32.712$, $p < .001$), demonstrating that individuals with a higher stuttering severity produced more stuttering-like disfluencies, but there was no interaction with Attention. Although there were also no significant interactions with Language, our pre-set hypotheses warranted planned contrasts on how Attention affected L1 and L2 performance (Hypothesis 2.3). These showed a significant effect with fewer stuttering-like disfluencies under divided attention in L2 ($z = -2.63$, $p < .01$), but not in L1 ($z < 1$). Multiple regressions on L2 proficiency (Hypothesis 2.5) under Full Attention ($F(5,64) = 2.455$, $p = .043$, $R^2 = .161$, Adjusted $R^2 = .095$) produced L2 LexTALE as predictor ($r^2 = -.005$, $p = .018$), with higher performance predicting fewer disfluencies (Hypothesis 1.4). Under Divided Attention, the model ($F(4,8) = 9.981$, $p = .003$, $R^2 = .833$, Adjusted $R^2 = .750$) showed L2 LexTALE as a predictor of fewer disfluencies ($t = -2.431$, $p = .018$) (Hypothesis 2.5).

Typical disfluency. The modelling on typical disfluencies showed a significant main effect of Language ($\chi^2(1) = 24.858$, $p < .001$), with more typical disfluencies in L2 (Hypothesis 1.2). There was also a main effect of Attention ($\chi^2(1) = 8.875$, $p = .003$), with more typical disfluencies in the divided attention condition (Hypothesis 2.2). There was no main effect of

Stuttering Severity ($\chi^2 < 1$). The only significant interaction was between Language and Attention ($\chi^2(1) = 26.144$, $p < .001$) (Hypothesis 2.4). Planned comparisons showed there were significantly more typical disfluencies under divided than under full attention in L1 ($z = 4.86$, $p < .001$), while there was no effect of Attention in L2 ($z = 1.49$, $p = .14$). Looking at language proficiency, no L2 measure predicted the proportion of disfluencies (Hypothesis 1.4 and 2.5).

3.3.2 Secondary task performance

The number of experimental trials was dependent upon the speed at which the subjects conducted the network description task. The average was 767 trials, with a minimum of 706, and a maximum of 979. Mean percentage of correct responses on the pitch discrimination task during L1 speech was 62.11% (95% CI [60.05, 64.16]), and 58.77% (95% CI [57.06, 60.47]) during L2 speech. A Wilcoxon signed-rank test showed that accuracy was higher in L1 than in L2 ($z = -3.24$, $p = .001$, *Mdn* = 3.18, 95% CI [1.25, 5.09]).

3.4 Spontaneous speaking versus network description

To analyse the effect of each task on disfluency, Wilcoxon signed-rank tests with Bonferroni corrections were performed. Bilingual PWS produced fewer stuttering-like disfluencies in the network description task than when speaking spontaneously, both within L1 ($z = -3.03$, $p < .01$, *Mdn* = -1.02, 98.33% CI [-4.33, -0.18]) and L2 ($z = -2.42$, $p = .03$, *Mdn* = -1.64, 98.33% CI [-6.79, 0.00]). Similarly, bilingual PWS produced fewer typical disfluencies in the network description task than in the spontaneous speaking task in L1 ($z = -5.78$, $p < .001$, *Mdn* = -2.10, 98.33% CI [-2.89, -1.55]) as well as L2 ($z = -5.66$, $p < .001$, *Mdn* = -2.51, 98.33% CI [-3.95, -1.76]).

4. Discussion

Thus far, systematic research on speech fluency in bilingual PWS is of great theoretical and clinical value, but scarce. Moreover, the few pioneer studies that assessed how stuttering manifests itself within the two languages of bilingual PWS have yielded inconsistent findings on differences between L1 versus L2 (see Van Borsel, 2011, for an overview). Even though there are theoretical reasons to predict increased stuttering in L2 relative to L1 speech, no earlier group study has ever reported a statistically reliable demonstration of such an effect. The aim of the current study was therefore to examine typical and stuttering-like disfluencies in L1 and L2 speech, also under dual task conditions, and taking into account language proficiency as a possible mediating factor.

4.1 Speech fluency in L1 and L2 of bilingual PWS

To investigate whether or not bilingual PWS are equally disfluent in both languages, we examined the frequency of typical and stuttering-like disfluencies in spontaneous speech and in a controlled network description task. Our subjects produced more stuttering-like disfluencies in their L2 than in their L1, a finding that is verified by the subjects' higher self-rated L2 stuttering severity scores (see Table 1). Although this is the first group study to statistically demonstrate increased stuttering in L2, our results are consistent with an earlier case study (Ardila et al., 2011) reporting a similar effect. Also, Lim et al. (2008) have provided consistent descriptive evidence of such a difference, and both Schäfer and Robb (2012) and Maruthy et al. (2015) have reported this effect, albeit only for function words (for content words, a reverse pattern was observed with increased stuttering in L1). We were, however, unable to verify the latter, as a distinction for word type in the spontaneous speech task did not yield any differences in L1 and L2 in the current study. In all, our results indicate that bilingual language control may indeed act as a functional analogue to linguistic secondary tasks (cf. Poarch & Bialystok, 2015), which have been shown to increase stuttering-like behaviour (see Metten et al., 2011, for an overview). Language control demands appear to increase the amount of attention that is devoted to (hypersensitive) speech monitoring, similar to imposing another linguistic secondary task (Metten et al., 2011), rendering the oversensitive monitor even more responsive. Furthermore, we observed that bilingual PWS also produced more typical disfluencies in their L2. This finding for typical disfluencies is consistent with prior studies that observed equivalent results in bilingual PWNS (Declerck & Kormos, 2012). It shows that the higher attentional/inhibitory control demands associated with speaking in a less proficient language (Costa & Santesteban, 2004; Meuter & Allport, 1999) increases the production of typical disfluencies.

Prior studies on stuttering in bilinguals have suggested that L2 proficiency is a potentially mediating factor in how stuttering manifests itself in the two languages of bilingual PWS (Lim et al., 2008). Furthermore, a negative association has been suggested between L2 proficiency and the production of typical disfluencies in bilingual PWNS (e.g. Kormos, 2006; Poulisse & Bongaerts, 1994). The results of the current study validate the earlier results obtained in PWNS. With the exception of typical disfluencies in the network description task, we generally found that performance on the L2 proficiency test LexTALE predicted both typical and stuttering-like disfluencies, with higher scores related to less disfluency.

4.2 The effect of a non-linguistic secondary task

The outcome of the current study provides empirical support for the idea that carrying out a secondary non-linguistic task during speech, namely a pitch discrimination task, decreases the frequency of stuttering-like disfluencies in bilingual PWS. Indeed, we observed fewer stuttering-like disfluencies under divided than under full attention, although this effect seemed to be restricted to L2. In other words, drawing attention away from speech monitoring seemed to have aided our subjects in their production of speech. This may indeed point toward the possibility that PWS have an overly sensitive speech monitor. As such, our results support theories such as the VCH (Vasiç & Wijnen, 2005) for speech and OPTIMAL (Wulf & Lewthwaite, 2016) for motor skills, posing that drawing attention toward from an automatised task may decrease performance on this task.

The fact that we did not find any facilitatory effects in L1 is possibly explained by our choice of secondary task. Similar to previous studies that did not report stuttering improvements as a result of dual-tasking (e.g. Kamhi & McOsker, 1982; Thompson, 1985; Vasiç & Wijnen, 2005), we, too, employed a simple non-linguistic secondary task where subjects only had to discriminate between one high and one low tone and press the corresponding button. This task may already have been sufficiently taxing when subjects were speaking in their more cognitively demanding L2, but not for their more automatised L1. In other words, there was more room for improvement because of the higher stuttering rate in the L2. Indeed, the mean percentage of stuttering in L2 under divided attention was still higher than the mean percentage of stuttering under full attention In L1. This proposition is furthermore corroborated by the outcome of studies that did employ a more demanding secondary task, such as a spatial working memory task (Eichorn et al., 2016; 2019) or a dot-pattern tracking task (Arends et al., 1988). These studies did observe a decrease in atypical disfluencies among PWS when dual-tasking.

Interestingly, and contrary to stuttering-like disfluencies, we observed that the frequency of typical disfluencies increased under divided attention, but only when bilingual PWS were speaking in their L1. The L1 findings are in line with studies that tested the effects of divided attention on the fluency of PWNS (e.g. Oomen & Postma, 2002). The lack of an effect of dividing attention within the L2 is further in line with prior work that did not observe an effect of a non-linguistic secondary task on typical disfluencies in the L2 of bilingual PWNS (Declerck & Kormos, 2012). It might be that speaking in a L2 requires substantial attention due to the language control demands that already operate as a secondary linguistic task. It appears that adding a third (non-linguistic) task may have no additional modulating effect on production of typical disfluencies (cf. Declerck & Kormos, 2012).

The discrepant findings between stuttering-like and typical disfluencies under conditions of divided attention with a non-linguistic secondary task suggest that the two disfluency types have a different cognitive origin. Stuttering-like disfluencies may, unlike typical disfluencies, not caused by difficulties at the level of speech planning. Instead, the current results fit with the hypothesis that stuttering-like disfluencies are (in part) caused by a deficit at the level of allocating attention to speech monitoring (e.g. Maxfield et al., 2015; Vasiç & Wijnen, 2005). Indeed, the VCH assumes problems with the post-articulatory speech monitor in PWS. If typical disfluencies already arise at the speech planning level, they cannot be reduced by tuning the perception-based monitor (i.e. based in feedback via the auditory and language comprehension systems; see also Levelt, 1983). Still, production of these errors would not affect (read: worsen) stuttering-like disfluency, as the post-articulatory speech monitor has been attuned by the secondary task. Although we believe that the specific finding of a reduction in stuttering-like disfluencies under divided attention fits well with the idea of a hypersensitive monitoring system, it is also conceivable that our data on the whole primarily reflect broader difficulties with attentional abilities, which are frequently observed in PWS (e.g. Doneva, 2020).

If additional linguistic demands indeed increase the proportion of stuttering-like disfluencies, as our results suggest, this type of disfluency should also occur more frequently in spontaneous speech than in the network description task. Indeed, the former task may be more cognitively demanding, as the content draws on long-term memory and generation of a discursive model is required. In addition, producing spontaneous speech may be more stressful than uttering sentences which all have the same grammatical structure and for which the content is already available, as is the case in the network description task (see also Declerck & Kormos, 2012). All these factors may lower speech monitoring demands during network description. Our results are in line with this assumption, as bilingual PWS were overall more fluent in the network description task than in the one-minute speaking task. As the current study did not combine the secondary task with the one-minute task, it is hard to draw strong conclusions about the impact of divided attention on spontaneous speaking. Nevertheless, we see no reason to assume that a secondary task would have a different effect on spontaneous speech. On the contrary, as spontaneous speech seems more inherently prone to disfluency than cued speech, there is even more room for improvement in stuttering-like disfluency, and yet, typical disfluencies may still increase.

Finally, we also observed that PWS were less accurate on the pitch discrimination task when speaking in the L2 than when speaking in the L1. This is further in line with our hypothesis that speaking in the L2 is more attention-demanding than speaking in the L1, which goes at the expense of the amount of available attention for the other, secondary task. It is also worth mentioning that performance on the pitch discrimination task was overall rather low, although performance was significantly higher than chance-level (50% accuracy). This suggests that both tasks (i.e. speech and the secondary task) are competing for shared attentional resources. The low performance on the non-linguistic secondary task is therefore consistent with the present hypothesis that relates stuttering to an attentional problem. It provides converging evidence that bilingual PWS invest a disproportionate amount of attention to speaking, even when speaking in the L1. The high allocation of attentional resources to speaking then might lead to a low performance on concurrent tasks, because there is not sufficient attention available to complete this secondary task.

4.3 Clinical implications

The outcome of the current study may also be of clinical interest. The present findings suggest that it might be worth further investigating whether clinical interventions may be enhanced by strategies that involve attentional training, which aims to teach PWS to allocate an appropriate amount of attention towards speech monitoring, reducing stuttering frequency. It has already been shown that PWS have impaired non-linguistic cognitive control abilities (Eggers, De Nil, & Van Den Bergh, 2013), which are important for goal-directed behaviour. This is not surprising, given that action monitoring and speech monitoring both rely on the same neural network (Arnstein, Lakey, Compton, & Kleinow, 2011). Such a link between linguistic and non-linguistic control abilities has also been found in other disorders, such as Attention Deficit Hyperactivity Disorder (ADHD; Engelhardt, Corley, Nigg, & Ferreira, 2010) and bilingual differential aphasia (Van der Linden, Dricot, et al., 2018; Van der Linden, Verreyt, et al., 2018), suggesting that both processes of monitoring are closely related and should likely be treated together. The current and prior studies thus indicate that linguistic phenomena such as speech pathologies and bilingualism should be considered in a larger cognitive perspective, in which the role of attention is important. Beneficial effects of non-linguistic, attentional training on stuttering frequency have already been observed in monolingual children who stutter. Nejati, Pouretemad, and Bahrami (2013) trained a group of 15 children who stutter with an attentional training programme called Neurocognitive Joyful Attentive Training (NEJATI). The authors observed that children not only improved their attentional abilities, but also their speech fluency (i.e. they stuttered less after than before therapy). As far as we know, the impact of this kind of training programme on the fluency of adult PWS has not been empirically tested. It should be noted, though, that the current findings suggest that attentional training may induce a trade-off, in the form of an increase in typical disfluencies. Although the idea of attentional training for PWS is promising, further research on the effects of such training programmes is therefore needed to fully understand whether or how this could benefit the quality of life of PWS.

4.4 Conclusion

The current study provides novel insights into the interaction between bilingualism and stuttering, and clarifies the possible underlying attentional causes of stuttering. First, our results show that bilingual PWS produce more typical and stuttering-like disfluencies in their L2 compared to their L1. Furthermore, a reduction in stuttering-like disfluencies and an increase in typical disfluencies under conditions of divided attention show that stuttering-like disfluencies should be dissociated from typical disfluencies because they are (at least partially) related to hypersensitive speech monitoring. Overall, the current study provides further support for the hypothesis that stuttering may originate from devoting too much attention to speech monitoring. They also show that the higher language control demands of speaking in a less proficient language increase the frequency of stuttering-like disfluencies in bilinguals who stutter.

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Table 1. *Mean demographic data for each language of the participants with 95% CIs between brackets.*

Test	L1	L2	*Difference*	*t(27)*
LEAP-Q - Speaking (10-point scale)	9.14 [7.66; 10.00]	6.68 [3.52; 9.84]	2.46 [1.84, 3.08]	6.80^{***}
LEAP-Q - Comprehension (10-point scale)	9.29 [7.79; 10.00]	7.86 [4.95; 10.00]	1.43 [0.27; 0.88]	5.30^{***}
LEAP-Q - Reading (10-point scale)	9.00 [6.87; 10.00]	7.46 [4.72; 10.00]	1.54 [0.96; 2.11]	5.50^{***}
Age of acquisition (years)	1.46 [0.00; 9.72]	8.32 [0.00; 16.86]	-6.86 [-9.55; -4.17]	-5.23^{***}
Use (%)	78.29 [56.38; 100.00]	21.71 [0.00; 43.62]	56.58 [47.91; 65.24]	13.48^{***}
LexTALE (%)	90.89 [78.76; 100.00]	71.73 [46.11; 97.36]	19.16 [15.02; 23.30]	9.69^{***}
OASES (raw score)	47.88 [30.13; 65.63]	50.05 [31.80; 68.30]	-2.17 [-3.99; -0.36]	-2.36^{*}

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 2. *Mean percentages of stuttering-like and typical disfluencies for the spontaneous speech and network description task. 95% confidence intervals are presented between brackets.*

	Stuttering-like		**Typical**	
	L1	L2	L1	L2
Spontaneous speech	9.08 [5.68; 12.48]	13.89 [9.69; 18.08]	3.67 [3.15; 4.20]	5.48 [4.76; 6.21]
Network description				
Overall	5.89 [4.88; 6.91]	9.16 [7.96; 10.36]	1.73 [1.61; 1.84]	2.78 [2.62; 2.94]
Full attention	6.37 [4.81; 7.92]	10.43 [8.57; 12.28]	1.44 [1.30; 1.58]	2.63 [2.41; 2.85]
Divided attention	5.41 [4.01, 6.73]	7.88 [6.36; 9.39]	2.02 [1.83; 2.20]	2.93 [2.70; 3.16]

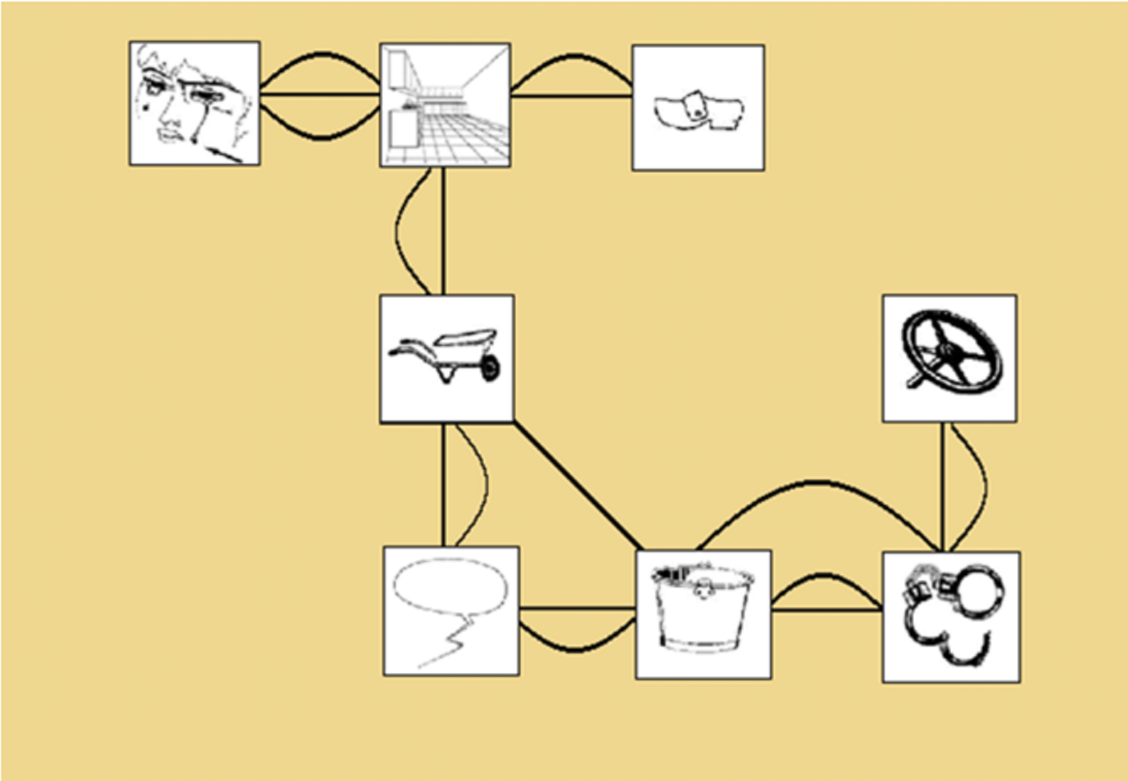

Figure 1. Example of a trial in the network description task.

Participants are asked to describe the path of a red dot that runs along the images.

Appendix

Spontaneous speech

Models Stuttering-like Disfluencies

Model 1: ErrorsProp ~ Language + (1 | Participant) + (1 | Task)
Model 2 ErrorsProp ~ Language + (1 + Language | Participant) + (1 | Task)
Model 3: ErrorsProp ~ Language + (1 + Language | Participant) + (1 + Language | Task)

	Df	AIC	BIC	Chisq	*p*
Model 1	4	810.65	823.13		
Model 2	6	793.73	812.43	20.929	< .001
Model 3	8	796.15	821.09	1.581	0.454

	Model 1		Model 2		Model 3	
	Chisq	*p*	Chisq	*p*	Chisq	*p*
Intercept	99.973	< .001	92.399	< .001	90.087	< .001
Language	108.424	< .001	26.107	< .001	20.864	< .001

Models Typical Disfluencies

Model 1: ErrorsProp ~ Language + (1 | Participant) + (1 | Task)
Model 2: ErrorsProp ~ Language + (1 + Language | Participant) + (1 | Task)
Model 3: ErrorsProp ~ Language + (1 + Language | Participant) + (1 + Language | Task)

	Df	AIC	BIC	Chisq	*p*
Model 1	4	3733.0	3749.8		
Model 2	6	3696.7	3722.0	40.28	< .001
Model 3	8	3700.7	3734.4	0.00	1.00

	Model 1		Model 2		Model 3	
	Chisq	*p*	Chisq	*p*	Chisq	*p*
Intercept	2291.8	< .001	1740.22	< .001	1740.21	< .001
Language	133.9	< .001	27.85	< .001	27.85	< .001

Description Network Task

Models Stuttering-like Disfluencies

Model 1: ErrorsProp ~ Language * Attention * StutteringProp + (1 | Subject) + (1 | Network)
Model 2: ErrorsProp ~ Language * Attention * StutteringProp + (1 + Language | Subject) + (1 | Network)
Model 3: ErrorsProp ~ Language * Attention * StutteringProp + (1 + Language + Attention | Subject) + (1 | Network)
Model 4: ErrorsProp ~ Language * Attention * StutteringProp + (1 + Language + Attention | Subject) + (1 + Language | Network)

	Df	AIC	BIC	Chisq	*p*
Model 1	10	4455.1	4505.2		
Model 2	12	4241.4	4301.6	217.7	< .001
Model 3	15	4091.0	4166.2	156.37	< .001
Model 4	17	4091.4	4176.7	3.5944	.166

	Model 1		Model 2		Model 3		Model 4	
	Chisq	*p*	Chisq	*p*	Chisq	*p*	Chisq	*p*
Intercept	436.9703	< .001	447.8720	< .001	378.7444	< .001	380.6561	< .001
Language	116.2016	< .001	7.1093	< .001	10.2759	.002	9.8734	.002
Attention	1.0848	.298	0.6493	.420	0.1064	.744	0.1039	.747
StutteringProp	48.4019	< .001	49.3014	< .001	41.7457	< .001	41.7137	< .001

Models Typical Disfluencies

Model 1: ErrorsProp ~ Language * Attention * StutteringProp + (1 | Subject) + (1 | Network)
Model 2: ErrorsProp ~ Language * Attention * StutteringProp + (1 + Language | Subject) + (1 | Network)
Model 3: ErrorsProp ~ Language * Attention * StutteringProp + (1 + Language + Attention | Subject) + (1 | Network)
Model 4: ErrorsProp ~ Language * Attention * StutteringProp + (1 + Language + Attention | Subject) + (1 + Language | Network)

	Df	AIC	BIC	Chisq	*p*
Model 1	10	15656	15717		
Model 2	12	15482	15556	177.56	< .001
Model 3	15	15422	15514	66.165	< .001
Model 4	17	15426	15530	0.0652	.968

	Model 1		Model 2		Model 3		Model 4	
	Chisq	*p*	Chisq	*p*	Chisq	*p*	Chisq	*p*
Intercept	1291.0789	< .001	1041.0774	< .001	945.0252	< .001	942.1039	< .001
Language	134.1087	< .001	22.5196	< .001	22.0730	< .001	22.0918	< .001
Attention	76.3511	< .001	77.3979	< .001	23.6030	< .001	23.6166	< .001
StutteringProp	1.0811	.298	1.0186	.313	1.0716	.301	1.0723	.301