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[bɪt] by [bɪʔ]: Variation in T-glottaling in Scottish Standard English

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Abstract
The present study investigates internal and external constraints conditioning variable T-glottaling, the realization of the voiceless alveolar stop /t/ as a glottal stop [ʔ], in supraregional Scottish Standard English. Drawing on phonemically annotated speech data from the Scottish component of the International Corpus of English, a total of 12,162 /t/ tokens produced by 138 speakers were extracted from eight formal speaking categories in the corpus and analyzed auditorily. The results showed that about 28% of the analyzed /t/ tokens were produced as glottal stops, with significant inter- and intra-speaker variability. The realization of T-glottaling is subject to both linguistic (phonetic context and word type) and social factors (age, gender, and speech style). Moreover, patterns of various types of T-glottaling differ from each other and constitute distinctive processes of ongoing sound change in Scotland.

Keywords: Scottish Standard English; T-glottaling; sociophonetics; ICE-Scotland

Introduction

T-glottaling, the realization of the voiceless alveolar stop /t/ as a glottal stop [ʔ], is a prominent phenomenon in English that has attracted copious attention from laypeople (see Kirkham and Moore [2016] for some popular comments on Ed Miliband's speech that were cited from political columns in the British press) and linguists alike. In the 21st century, T-glottaling has been documented for numerous speakers in urban centers all over the UK (e.g., Schleef, 2013 for London and Edinburgh; Straw & Patrick, 2007 for Ipswich; Drummond, 2011 for Manchester; Williams & Kerswill, 1999 for Reading and Milton Keynes; Stuart-Smith, Timmins, & Tweedie, 2007 for Glasgow; Mees & Collins, 1999 for Cardiff), in Received Pronunciation (RP; e.g., Fabricius, 2002), as well as globally (Holmes, 1995 for New Zealand English; Roberts, 2006 for Vermont English; Eddington & Taylor, 2009 for American English; Gut, 2005 for Singapore English). In Britain, this sound change has become so pervasive

that it has been termed "a stereotype of British speech" by Smith and Holmes-Elliott (2017:324), with Trudgill (1999:136) calling this phenomenon "one of the most dramatic, widespread and rapid changes to have occurred in British English in recent times."

The present study sets out to investigate the current status of T-glottaling in Scottish Standard English (SSE), a standardized variety of Scottish English typically spoken by educated middle-class speakers in Scotland (Stuart-Smith, 2008:48). SSE developed in the Scottish Lowlands from the 17th century onwards when it was adopted by the upper classes and a diglossic situation with Scots emerged (Maguire, 2012). This diglossic situation is traditionally described as a bipolar continuum ranging from Scots to SSE (Aitken, 1984:520; Johnston, 2007; Stuart-Smith, 2008) with the term "Scottish English" used to encompass all of the varieties on this continuum, while more recent descriptions also consider the influence from Standard Southern British English (SSBE; Schützler, 2014) on Scottish English. The complex linguistic situation in Scotland has given rise to the sociolinguistic uniqueness of SSE, which is on the one hand a localized and geographically grounded norm conditioned by a number of varieties of Scots and a standardized middle-class norm affected by SSBE and RP on the other. Although T-glottaling has been widely attested in varieties of English and various patterns and influencing factors thereof have been identified, little empirical evidence exists on this sound change in supraregional SSE. The current study aims to explore how this sound change correlates with both language-internal and language-external constraints. Furthermore, by comparing patterns of T-glottaling in SSE with RP, Scottish Englishes, and other English varieties, this study hopes to contribute to our understanding of the complexity of sound variation and change. Specifically, the following research questions will be addressed:

(1) How is T-glottaling distributed in supraregional SSE?
(2) Which language-internal and language-external factors condition patterns of T-glottaling in SSE?
(3) Do patterns of and underlying factors affecting T-glottaling in SSE differ from other varieties of English (especially RP and other Scottish Englishes)?

T-glottaling as a sociolinguistic phenomenon: Patterns and constraints

Although its origin is still debated, T-glottaling appears to constitute a polygenetic phenomenon that has spread from both Glasgow (Macafee, 1997:528) and lower-class London speech (see also Smith & Holmes-Elliott, 2017:324) to many accents all over Britain and worldwide. A number of studies have shown this phonological process to be diffusing and developing rapidly in various directions: from lower-class to middle-class and younger to older speakers as well as from informal to formal speech. For example, there is a marked increase of T-glottaling especially among younger speakers (e.g., Marshall, 2001; Smith & Holmes-Elliott, 2017; Tollfree, 1999), who appear to perceive glottal variants of /t/ as more friendly, whereas they consider the alveolar variants as more articulate, reliable, and posh (Schleef, 2013). Moreover, T-glottaling is now also increasingly used in standard accents and varieties (see Badia Barrera, 2015 and

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Fabricius, 2002 for RP; Miller, 2019 for SSE) and in formal styles (see Milroy, Milroy, Hartley, & Walshaw, 1994 for 10-year-old girls in Tyneside).

Wells (1997) described three types of T-glottaling that differ in the phonetic environment in which they occur:

(1) Type 1: The realization of /t/ as a glottal stop before a following obstruent or sonorant consonant both word-medially, as in *Scot*[ʔ]*land*, and across word boundaries, as in *not*[ʔ] *now*.
(2) Type 2: The realization of /t/ as a glottal stop in word-final position before a vowel, as in *not*[ʔ] *only*, or a pause, as in *not*[ʔ]#.
(3) Type 3: The realization of /t/ as a glottal stop in word-medial intervocalic position, as in *butt*[ʔ]*er*, and before a syllabic /l/, as in *bott*[ʔ]*le*.

Wells (1997) furthermore stated a chronological relationship between these three types of T-glottaling in RP: the first type of T-glottaling appeared in the mid-20th century, while the second type was introduced by younger speakers from the late 20th century onwards. In contrast, T-glottaling in word-medial intervocalic position and before a syllabic consonant (Type 3) is not used by RP speakers at all, as it is stigmatized and associated with lower-class speech. Wells' impressionistic description is corroborated by an empirical study by Badia Barrera (2015), who analyzed young RP speakers and showed that T-glottaling of the first type occurs almost categorically in their informal speaking style. T-glottaling of Type 2 is produced variably, while the realization of /t/ as a glottal stop in word-medial intervocalic position and before a syllabic /l/ is still very rare. Whether these different rates of T-glottaling for the three "Wells' types" that exist in RP can also be found in the standard variety spoken in Scotland has not been investigated yet and will be the focus of this study.

Like for RP, different rates of T-glottaling for the three types described by Wells are also found in other varieties of British English: Straw and Patrick (2007:391) showed in their overview that the realization of /t/ as a glottal stop before a following obstruent or sonorant consonant (Type 1) was almost categorical in a wide range of British accents, whereas the realization of /t/ as a glottal stop before a vowel or a pause (Type 2) was not present to the same extent in the speech of all speakers. It varied with the social factors of age, gender, and class, such that it was used more frequently by younger than by older speakers (e.g., Docherty & Foulkes, 1999 for Derby) and prevocalically more by lower-class than by middle-class boys and girls in Reading, Hull, and Milton Keynes (Williams & Kerswill, 1999). T-glottaling in word-medial intervocalic position (Type 3) was not included in Straw and Patrick's (2007) overview, but Marshall (2001) found systematic variation of its frequency with age and gender for speakers in the North-East of Scotland: it was predominately used by both male and female teenagers as well as by male 8–12-year olds but not by older speakers or by female 8–12-year olds. The social variation of T-glottaling of the Types 2 and 3 thus suggests that these processes reflect ongoing language change, which might spread further. Whether these results can be interpreted as an implicatory relationship between the three types of T-glottaling—that is, whether T-glottaling spreads in a variety of English in the order Type 1 > Type 2 > Type 3—is still an open question, which we will test in this study.

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Besides the following phonetic environment as described in the three types by Wells (1997), other linguistic factors been found to affect the rate of T-glottaling, outlined below.

(1) The preceding phonetic environment, where vowels trigger T-glottaling most (see Roberts, 2006 for Vermont speakers; Schleef, 2013 for young speakers in London and Edinburgh).
(2) The position of /t/, with word-final /t/ showing more glottaling than word-medial /t/ (e.g., Kirkham & Moore 2016 in a case study of the politician Ed Miliband's speech; Schleef, 2013).
(3) Word frequency and word type, with frequent words and function words favoring T-glottaling (e.g., Badia Barrera, 2015 for young RP speakers; Schleef, 2013).

Moreover, different speaking styles exhibit different degrees of T-glottaling in that informal conversations show a higher frequency of its occurrence than reading passages (Badia Barrera, 2015; Schleef, 2013; see also Stuart-Smith et al., 2007 for Glasgow English), an effect that is especially strong for /t/ in word-medial position (e.g., Schleef, 2013). However, most studies carried out so far, with the exception of Schleef (2013) and Badia Barrera (2015), only include a small number of linguistic factors and typically do not consider all types of T-glottaling so that the relative influence of these linguistic factors on the rate of T-glottaling is still largely unknown.

Previous studies on T-glottaling in Scottish Englishes

Although T-glottaling in Scotland appears well researched in terms of its diachronic spread and social distribution, extant studies on contemporary Scottish English have certain limitations (see Table 1 for an overview of recent studies). First, they are mostly restricted to speakers in Glasgow (e.g., Stuart-Smith, 1999; Stuart-Smith et al., 2007) and rural communities in the Northeast of Scotland (e.g., Marshall, 2001; Smith & Holmes-Elliott, 2017). Second, most of the studies are based on small samples of socially stratified speakers and differ sharply in the types of T-glottaling they analyze, ranging from intervocalic word-medial /t/ only (Type 3) (Marshall, 2001), word-final /t/ only (Hall-Lew, Markl, Papineau, & Sung, 2019) to Types 2 and 3 only (Stuart-Smith, 1999), but excluding some phonetic and prosodic environments. Also, studies differ sharply in the number of linguistic and social factors they investigate that potentially impact the occurrence of T-glottaling.

As a result, our knowledge of T-glottaling in Scottish Englishes is still partly patchy and sometimes contradictory. The factors SOCIAL CLASS and AGE have been established as influencing the rate of T-glottaling in various forms of Scottish English: Glaswegian working-class speakers show a considerably higher rate of T-glottaling than middle-class speakers (Stuart-Smith, 1999; Stuart-Smith et al., 2007) and younger speakers produce more T-glottaling than older speakers (for Glasgow, see Stuart-Smith, 1999; Stuart-Smith et al., 2007; for the Buckie dialect, see Smith & Holmes-Elliot, 2017; for intervocalic /t/ in the Huntly dialect, see Marshall, 2001), but no findings exist yet for speakers of the Scottish standard variety SSE. Furthermore, gender has not been found

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Table 1. Empirical studies of T-glottaling in Scottish English, their research foci, data, and analyses

	Area and focus	Data	Environments in which /t/ was investigated	Analyzed variants	Factors investigated
Stuart-Smith (1999)	Glasgow; sociolinguistic patterns change in last decades	32 socially stratified (age, gender, class) speakers; conversations and wordlists	Word-medial and word-final /t/; pre-consonantal position excluded	[t], [ʔ], and [ɾ]	Following phonetic context, social class, age, gender, speaking style
Marshall (2001)	Huntly (Northeast Scotland); change in progress, accent levelling, and standardization	64 socially stratified (age, gender) speakers; interviews and picture lists	Word-medial /t/, intervocalic	[t] and [ʔ]	Age, gender
Stuart-Smith et al. (2007)	Glasgow; co-variation with other phonological features; factors explaining patterns	32 socially stratified (age, gender, class) speakers (same as Stuart-Smith, 1999); word list and interview	Not specified	[t], [ht], [ts] [ʔt], [t], [ɾ] [ø], and [ʔ]	Age, gender, social class, speaking style
Schleef (2013)	Edinburgh comparison with London English; variation with language-internal and -external factors	21 teenagers; interviews, conversations, and reading task	Word-medial and word-final /t/; /t/ preceded by fricatives, plosives, and in consonant clusters; excluded onset /t/ in stressed syllables; excluded high-frequency tokens (*it, that, but* …) capped	[t] versus [ʔ]; other realizations collapsed with [t]	Preceding phonetic context, following phonetic context, position (word-final, word-medial), grammatical category, number of syllables, lexical frequency, speaking style, gender, age

(*Continued*)

Table 1. (*Continued.*)

	Area and focus	Data	Environments in which /t/ was investigated	Analyzed variants	Factors investigated
Smith & Holmes-Elliott (2017)	Buckie (Northeast Scotland); change in progress and stylistic change	24 working-class speakers; interviews	Word-medial and word-final /t/; /t/ with following non-sonorant consonant; excluded high-frequency tokens (*it, that, but*) capped	[t] and [ʔ]; other variants excluded	Following phonetic environment, syllabic position, age, gender, interlocutor
Hall-Lew et al. (2019)	Many regions of Scotland; origin of T-glottaling variation across regions and with social variables	17 women with diverse backgrounds	Word-final /t/	[t] and [ʔ]	Following phonetic environment, number of syllables, age, class, region, occupation, formality, interlocutor
Miller (2019)	Single speaker stylistic variation	Two interviews with Lorraine Kelly	Word-medial and word-final /t/; /t/ in onset position; excluded /t/ followed by /t/ and high-frequency tokens *(it, that, but*) capped	[t] and [ʔ] other variants excluded	Interlocutor

to play a role for either Glaswegian speakers (Stuart-Smith, 1999; Stuart-Smith et al., 2007) or Edinburgh teenagers (Schleef, 2013) but does influence the rate of T-glottaling for older speakers of the Buckie dialect (Smith & Holmes-Elliot, 2017) as well as in the Huntly dialect (Marshall, 2001).

As far as language-internal factors are concerned, the following phonetic environment favoring T-glottaling has been variously identified as consonant (C) > vowel (V) > pause (P) (Hall-Lew et al., 2019 but with regional variation), C > P > V (Schleef, 2013 for word-final /t/; no influence for word-medial /t/), and P > V (Stuart-Smith, 1999 with variation with age and gender). For the Buckie dialect, a completely different hierarchy was found with highest rates of medial T-glottaling followed by a syllabic /l/ (*bottle*), word-final /t/ before vowels Coda#Vowel (*that is*), and intervocalic /t/ (*pretty*), contexts that are highly disfavored in other varieties of Scottish English (Smith & Holmes-Elliott, 2017). In general, speaking style has been found to influence the rate of T-glottaling in Scottish English, which is more frequent in conversations than in word list readings (Schleef, 2013; Stuart-Smith, 1999; Stuart-Smith et al., 2007), but young working-class speakers in Glasgow (Stuart-Smith et al., 2007) and Edinburgh teenagers (Schleef, 2013) also produce high rates of T-glottaling in reading. The influence of preceding phonetic environment and word class has only been analyzed for Edinburgh teenagers so far (Schleef, 2013) and awaits confirmation for other speakers across Scotland.

It is worth noting that none of the previous studies analyzed all three types of T-glottaling described by Wells (1997). Therefore, the question of whether these three types occur at different rates in Scottish English, as they do in RP, is still open. However, Stuart-Smith's (1999) study of Glaswegian speakers showed that middle-class speakers produced more T-glottaling of Type 2 than of Type 3 (only intervocalic position was included), with overall higher rates for younger than older speakers. Thus, while for older middle-class speakers, /t/ in intervocalic position was still the norm in the late 1990s, for younger middle-class speakers, a glottal stop in this position had become an option with an occurrence of about 35% in conversational speaking style. It would, therefore, be interesting to explore whether this rate has increased in the past decades and whether T-glottaling of Type 3 has diffused to more formal speech styles in Scotland.

The present study investigates patterns of T-glottaling in SSE, which will be operationalized in this study as the speech that is produced by Scottish speakers in formal situations such as when giving a speech in parliament. Given the uniqueness of SSE as a variety that intersects both localized and standardized norms, the investigation of T-glottaling in SSE could not only contribute to our understanding of how this sound change is distributed in the specific variety but also shed light on the complex nature of sound variation and change more generally. Specifically, we will analyze the influence of the social factors[1] AGE and GENDER as well as of the linguistic factors FOLLOWING AND PRECEDING PHONETIC CONTEXT, WORD TYPE, and SPEAKING STYLE on the rate of T-glottaling. Finally, we will interpret the results with a view of testing the hypothesis that the three types of T-glottaling are developing in the order Type 1 > Type 2 > Type 3 in SSE as proposed by Wells (1997) for RP and compare the diffusion patterns and underlying constraints of T-glottaling in SSE with RP and other Scottish English varieties to gain a more accurate insight into the status of SSE.

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Methods

The data analyzed in the present study were drawn from the Scottish component of the International Corpus of English (ICE-Scotland; Schützler, Gut, & Fuchs 2017), which contains both written (400,000 words collected from 17 written text types) and spoken data (600,000 words from 15 spoken genres), with the latter having time-aligned phonemically annotated transcriptions. Eight types of formal speeches that are assumed to specifically invoke the use of SSE were selected: broadcast discussions, broadcast interviews, broadcast news, broadcast talks, demonstrations, legal presentations, parliamentary debates, and unscripted speeches. These include both scripted (e.g., broadcast news) and unscripted (e.g., broadcast discussions) types of speech and comprise a total of 172,328 words. There is a total of 136 speakers included in the corpus (55 women, 81 men), aged between 17 and 78, who have various professional backgrounds and come from all over Scotland.

The realization of each /t/ token was analyzed auditorily by two independent coders using *Praat* (Boersma, 2001), which follows the methodology of the majority of studies on T-glottaling in Scottish English (e.g., Macaulay, 1977; Schleef, 2013; Stuart-Smith, 1999). We excluded minority variants of /t/ such as taps [ɾ] and the glottalized voiceless alveolar stop [ʔt] and concentrated on the binary distinction between [t] and [ʔ] (see also Drummond, 2011; Fabricius, 2002; Schleef, 2013; Smith & Holmes-Elliott, 2017; Straw & Patrick, 2007), with [ʔ] possibly including other articulations such as creaky voice that give the auditory impression of a glottal stop. Both word-medial and word-final /t/ were analyzed, but words with /t/ in the following environments were excluded (see Schleef, 2013):

(1) when /t/ occurs in coda consonant clusters such as in *mint* and *thirst*;
(2) word-final /t/ with a following /t/ or /d/ in the onset position of the following word (e.g., *that day*);
(3) word-medial /t/ for which the stress pattern normally blocks T-glottaling (i.e., when /t/ is the onset consonant of a stressed syllables as in *tutorial*).

For the function words with high frequency, only the first 10 occurrences were included for each speaker (see also Schleef, 2013). This generated a total of 12,162 analyzed tokens of /t/ with 7,125 of them in the word-final position and 5,037 in the word-medial position. Each token was further coded for both language-internal and -external factors, with the distributions shown in Table 2.

For the statistical analysis, mixed-effects logistic regression models with the presence or absence of T-glottaling as dependent variable and SPEAKER and WORD as random intercepts were fitted using the package *lme4* (Bates, Maechler, Bolker, & Walker, 2014) in *R* (version 4.2.1; R Core Team, 2018). Fixed predictors include the internal factors FOLLOWING CONTEXT, PRECEDING CONTEXT, TYPE, and WORD TYPE, as well as the external factors GENDER, AGE, and SPEECH STYLE. The best models were selected using the *anova()* function. Post-hoc pairwise comparisons with Bonferroni corrections were conducted in the *lsmeans* package (Lenth, 2016) and its successor, the *emmeans* package (Lenth, 2018).

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Table 2. Overview of predictors and distribution of /t/ tokens

Factor	Levels	Token number	
		Word-final /t/	Word-medial /t/
FOLLOWING CONTEXT	Vowel	2222	3841
	Obstruent (affricative, fricative, plosive)	2044	186
	Sonorant consonant (glide, non-syllabic liquid, nasal)	1117	848
	Pause	1742	N/A
	Syllabic liquid	N/A	162
PRECEDING CONTEXT	Vowel	6085	3931
	Liquid	N/A	104
	Nasal	N/A	1002
TYPE	Type 1	4195	
	Type 2	3964	
	Type 3	4003	
SPEECH STYLE	Scripted (bnew, btal, leg, nbtal, parl)	4922	3884
	Unscripted (bdis, dem, unsp)	2203	1153
WORD TYPE	Content word	3653	4757
	Function word	3472	280
GENDER	Female	2607	1979
	Male	4518	3058
AGE	Continuous	7125	5037

Note on speech style categories: bnew = broadcast news; btal = broadcast talks; leg = legal presentations; nbtal = non-broadcast talks; parl = parliamentary debates.

Results

Descriptive statistics

An overview of the realization of /t/ according to its position across all speakers is shown in Table 3. Overall, 27.8% of the analyzed tokens were realized as [ʔ]. T-glottaling is more likely to occur in word-final position (38.8%) than in word-medial position (12.3%).

Table 3. Overall distribution of [t] and [ʔ] for /t/

	Word-final /t/		Word-medial /t/		Total	
	N	%	*N*	%	*N*	%
[ʔ]	2763	38.8	622	12.3	3385	27.8
[t]	4362	61.2	4415	87.7	8777	72.2
Total	7125	100	5037	100	12,162	100

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Zooming into the relative distribution of /t/ by different following phonetic contexts, Figures 1 and 2 illustrate that considerable differences in the rate of T-glottaling exist across the four following contexts. For word-final /t/, more than half of the tokens were produced as [ʔ] either when followed by a sonorant consonant (56.4%) or when followed by an obstruent (54.7%) (Type 1). Nearly a third of the instances of

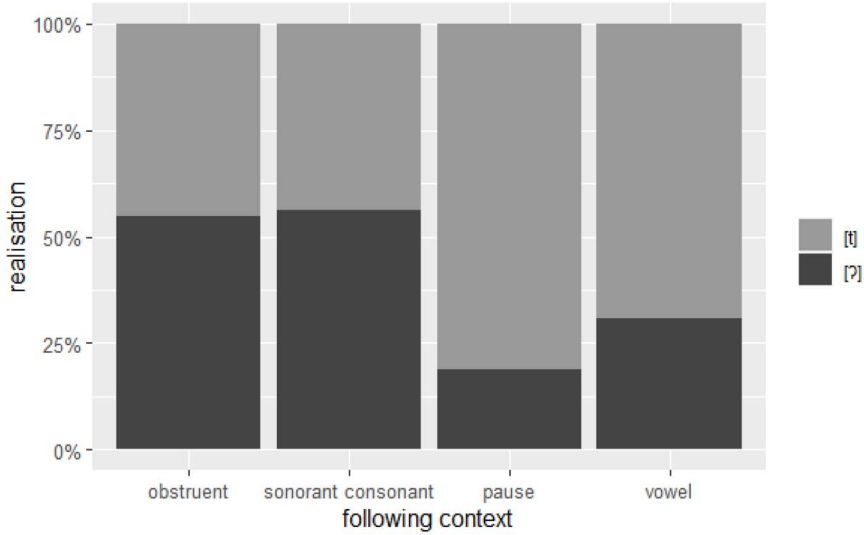

Figure 1. Relative distribution of word-final /t/ by following contexts.

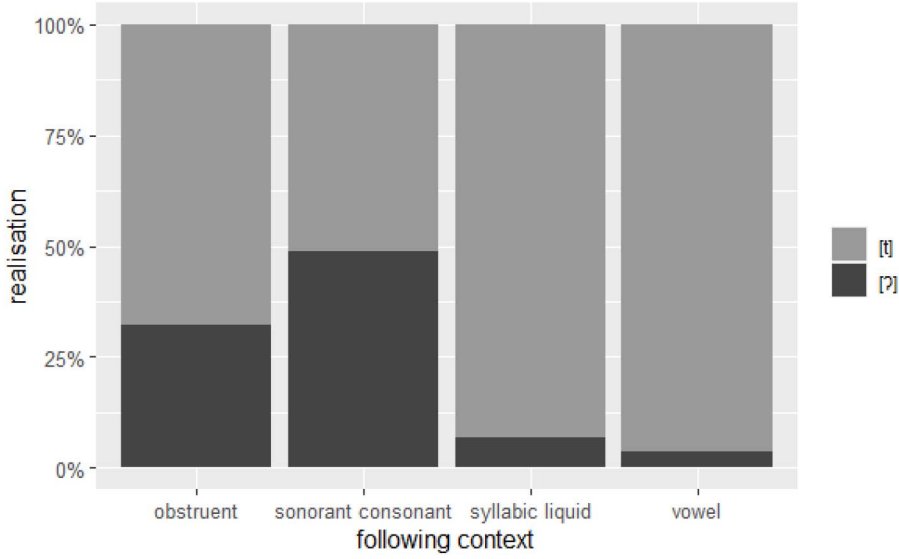

Figure 2. Relative distribution of word-medial /t/ by following contexts.

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/t/ preceding a vowel were realized as a glottal stop (30.8%), while only 18.9% of the tokens with a following pause were produced as [ʔ].

Regarding word-medial position, Figure 2 shows that T-glottaling occurs most frequently with a following sonorant consonant, with nearly half of the tokens (48.7%) realized as [ʔ], while 32.3% of the word-medial /t/ with a following obstruent was produced as [ʔ]. Following syllabic liquids and vowels, on the other hand, did not favor word-medial T-glottaling, with only 6.8% and 3.6% of the tokens in the respective context being realized as glottal stops.

Figures 1 and 2 indicate that, for both word-final and word-medial /t/, the use of a glottal stop is most likely to occur with a following sonorant consonant, with approximately half of the tokens being realized as [ʔ]. The second favorable context involves /t/ followed by an obstruent for both positions. Word-medial T-glottaling preceding a syllabic liquid or a vowel, on the other hand, was found to be extremely rare.

Multivariate analysis of word-final and word-medial T-glottaling

As different patterns of T-glottaling were found for word-final and word-medial positions, separate statistical models were fitted for them to investigate underlying internal and external factors affecting their respective distribution (see Schleef, 2013). Table 4 shows the best-fit mixed-effects logistic regression model for the realization of word-final /t/. FOLLOWING CONTEXT, WORD TYPE, AGE, and SPEECH STYLE were found to be statistically significant in conditioning word-final T-glottaling. Specifically, the

Table 4. Best-fit mixed-effects logistic regression model for the realization of word-final /t/ ($n = 7125$) as dependent variable, with SPEAKER and WORD as random intercepts (Predicted outcome: [ʔ]. Level of significance: $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$)

Fixed effects	Levels	Estimate	Std. error	*z*-value	$p <$	*N*	%
(Intercept)		1.16	.47	2.46	.014*		
FOLLOWING CONTEXT	Sonorant consonant	.41	.11	3.80	.000***	1117	56.4
	Pause	−2.08	.11	−18.62	.000***	1742	18.9
	Vowel	−1.23	.09	−13.72	.000***	2222	30.8
	(Obstruent)					2044	54.7
AGE	Continuous	−.05	.01	−5.86	.000***		
WORD TYPE	Function word	1.70	.39	4.33	.000***	3472	56.2
	(Content word)					3653	22.2
SPEECH STYLE	Unscripted	1.07	.19	5.69	.000***	2203	55.8
	(Scripted)					4922	31.2
Random effects	**Type**	**Variance**	**Std. dev**				
SPEAKER	(Intercept)	1.40	1.19				
WORD	(Intercept)	2.08	1.44				
		Min.	**Median**	**Max.**			
Scaled residuals		−9.98	−.14	7.14			

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realization of word-final /t/ is conditioned by WORD TYPE ($p < .001$), with function words favoring T-glottaling more than content words. The following phonetic contexts that word-final /t/ occurs in also play a statistically significant role, showing the hierarchy of sonorant consonant ($p < .001$) > obstruent > vowel ($p < .001$) > pause ($p < .001$). For the impact of following contexts, pairwise comparisons with Bonferroni correction were further conducted. Results show that the effects of the four following contexts are significantly different from each other ($p < .001$). In terms of social predictors, GENDER did not reach statistical significance and was eliminated by the best-fit model. AGE ($p < .001$) exerted an important impact, with younger speakers producing [ʔ] more frequently than older speakers, suggesting that the rates of producing a glottal stop tend to decrease with increasing speaker age. The realization of /t/ is further controlled by SPEECH STYLE ($p < .001$), with T-glottaling being more likely to occur in unscripted speech categories (e.g., broadcast interviews) compared with the scripted ones (e.g., legal presentations).

The constraints that appear to affect the patterning of word-medial /t/ are similar to those found for word-final /t/. Table 5 shows the best-fit mixed-effects model for word-medial /t/ and the significant factors thereof, including FOLLOWING CONTEXT, AGE, and SPEECH STYLE. Unlike word-final /t/, the effects of WORD TYPE on word-medial T-glottaling did not reach statistical significance. The factors PRECEDING CONTEXT and GENDER were eliminated by the best-fit model. Regarding the following contexts that medial /t/ precedes, sonorant consonants ($p = .008$) were found to be the most favorable context for glottal replacement, followed by obstruents, while a following vowel ($p < .001$) and a following syllabic liquid ($p < .001$) disfavored glottal

Table 5. Best-fit mixed-effects logistic regression model for the realization of word-medial /t/ ($n = 5037$) as dependent variable, with SPEAKER and WORD as random intercepts (Predicted outcome: [ʔ]. Level of significance: $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$)

Fixed effects	Levels	Estimate	Std. error	*z*-value	$p <$	*N*	%
(Intercept)		.56	1.32	.42	.674		
FOLLOWING CONTEXT	Sonorant consonant	−1.98	.74	−2.67	.008**	848	48.7
	Syllabic liquid	−7.30	1.57	−4.67	.000***	162	6.8
	Vowel	−5.28	.63	−8.40	.000***	3841	3.6
	(Obstruent)					186	32.3
AGE	Continuous	−.09	.02	−4.82	.000***		
SPEECH STYLE	Unscripted	1.53	.44	3.51	.000***	1153	21.3
	(Scripted)					3884	9.7
Random effects	**Type**	**Variance**	**Std. dev**				
SPEAKER	(Intercept)	4.92	2.22				
WORD	(Intercept)	21.36	4.62				
		Min.	**Median**	**Max.**			
Scaled residuals		−7.37	−.02	19.13			

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stops. Here, pairwise comparisons with Bonferroni correction showed that the effects of sonorant consonants and obstruents are significantly different from the effects of syllabic liquids ($p < .01$) and vowels ($p < .001$). Differences between the other contexts did not reach statistical significance. Like for word-final /t/, AGE exerted a significant impact on word-medial /t/, with [ʔ] occurring more frequently in the speech of younger speakers than older speakers ($p < .001$). Likewise, unscripted speaking styles promoted T-glottaling word-medially more than the scripted ones ($p < .001$).

Multivariate analysis of T-glottaling by Wells' type

Considering that the three types of T-glottaling proposed by Wells (1997) were found to have different realization rates in specific varieties of English, with the variable patterns being affected by different social factors (e.g., Badia Barrera, 2015; Marshall, 2001; Straw & Patrick, 2007), statistical modelling was further carried out for the realization of /t/ in both word-final and word-medial positions with TYPE as an internal fixed predictor and SPEECH, GENDER, and AGE as external fixed predictors. Interactions between TYPE and the three social factors were also tested by the mixed-effects logistic regression model. Table 6 shows that the four factors as well as their interactions (TYPE*AGE, TYPE*GENDER, and TYPE*SPEECH STYLE) exerted statistically significant influence on T-glottaling in SSE. Figures 3–5 show the patterns of T-glottaling under the influence of the interactions of the factors predicted by the model.

As shown in Table 6, the percentage of T-glottaling differs considerably across the three different types in SSE. As expected, Type 1 (i.e., T-glottaling preceding an obstruent or a sonorant consonant both word-finally and word-medially) is shown to be the most favorable phonetic context for the use of a glottal stop (53%), followed by Type 2 (i.e., word-final T-glottaling preceding a vowel or a pause; 25.6%), while Type 3 (i.e., word-medial T-glottaling preceding a vowel or a syllabic liquid) is extremely rare (3.7%). Post-hoc pairwise comparisons with Bonferroni correction on TYPE show that the effects of the three types on T-glottaling are significantly different from each other ($p < .001$).

Figure 3 shows that the realization of the three types of T-glottaling is constrained by speaker age ($p = .002$). Overall, the percentage of T-glottaling decreases with the increase of speaker age in all three types. Specifically, Type 1 is used by all speakers, albeit with younger speakers producing more glottal stops than older speakers. This is similar for Type 2, yet with a significantly lower overall rate of occurrences compared with Type 1 ($p < .001$). Type 3, on the other hand, only occurs among young speakers; speakers aged over 40 use the alveolar variant [t] categorically in this phonetic context ($p < .001$)[2].

The results of the mixed-effects model further suggest significant effects of GENDER on the production of glottal stops for /t/ ($p = .031$). As Figure 4 shows, a distinction between men and women in the use of T-glottaling is present only in Type 1, with female speakers using glottal stops more frequently than their male counterparts across all age groups. T-glottaling in the other two types did not show major differences between women and men.

Figure 5 demonstrates the effects of SPEECH STYLE on the three types of T-glottaling ($p < .001$). As can be seen, all three types occurred in both scripted and unscripted

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Table 6. Mixed-effects logistic regression model for the realization of /t/ ($n = 12{,}162$) as dependent variable, with SPEAKER and WORD as random intercepts (Predicted outcome: [ʔ]. Level of significance: $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$)

Fixed effects	Levels	Estimate	Std. error	*z* value	$p <$	*N*	%
(Intercept)		.52	.48	1.08	.280		
TYPE	Type 2	−.50	.31	−1.62	.105	3964	25.6
	Type 3	−.93	.47	−1.99	.047*	4003	3.7
	(Type 1)					4195	53
AGE	Continuous	−.03	.01	−3.05	.002**		
GENDER	Male	−.47	.22	−2.16	.031*	7576	26.1
	(Female)					4586	30.7
SPEECH STYLE	Unscripted	.68	.19	3.52	.000***	3356	44
	(Scripted)					8806	21.7
INTERACTIONS	Type 2: age	−.03	.01	−4.85	.000***		
	Type 3: age	−.07	.01	−6.43	.000***		
	Type 2: unscripted	.64	.14	4.50	.000***		
	Type 3: unscripted	.85	.26	3.21	.001**		
	Type 2: male	.32	.15	2.24	.025*		
	Type 3: male	.59	.27	2.22	.026*		
Random effects	**Type**	**Variance**	**Std. dev**				
SPEAKER	(Intercept)	1.48	1.22				
WORD	(Intercept)	2.25	1.50				
		Min.	**Median**	**Max.**			
Scaled residuals		−8.58	−.09	11.19			

speech with the latter being more favorable, albeit with distinctive patterns. As regards Type 1 T-glottaling, this is used more frequently in unscripted speech than scripted speaking styles across all age groups. For Type 2, the distinction between the two speaking styles is the most marked among young speakers and decreases with increasing speaker age. Type 3 exhibits a similar trend, but only for speakers under 40 years of age. Again, older speakers were predicted to use the alveolar [t] almost categorically in this phonetic context.

After examining the global distribution of T-glottaling in relation to various social factors across all speakers, we further explored individual realization of T-glottaling. Based on 91 speakers who produced words with /t/ in each of the three phonetic environments described by Wells (1997) at least 10 times, significant inter- and intra-speaker variability was identified. That is, different degrees of T-glottaling exist between and within individual speakers (see Appendix A for individual realization plots and Appendix B for age, gender, and speech category of the 91 speakers). Figure 6 presents

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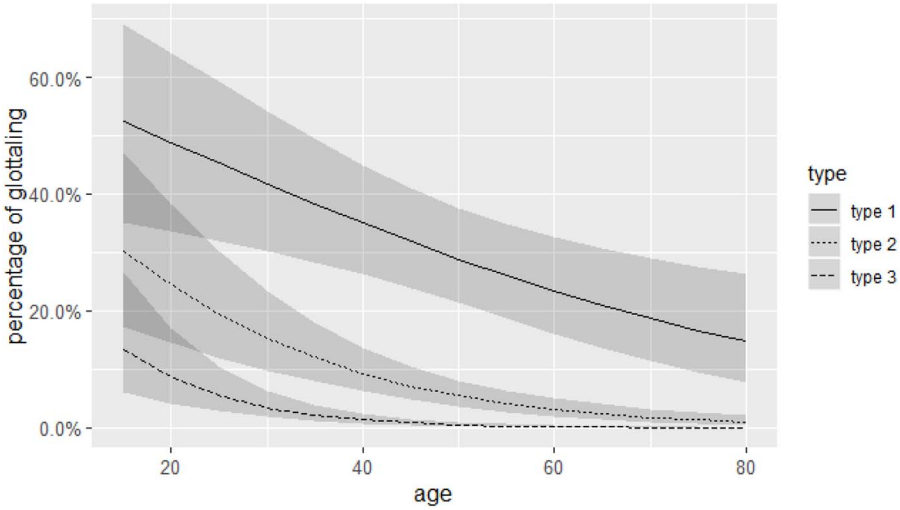

Figure 3. Effects of AGE on the three types of T-glottaling.

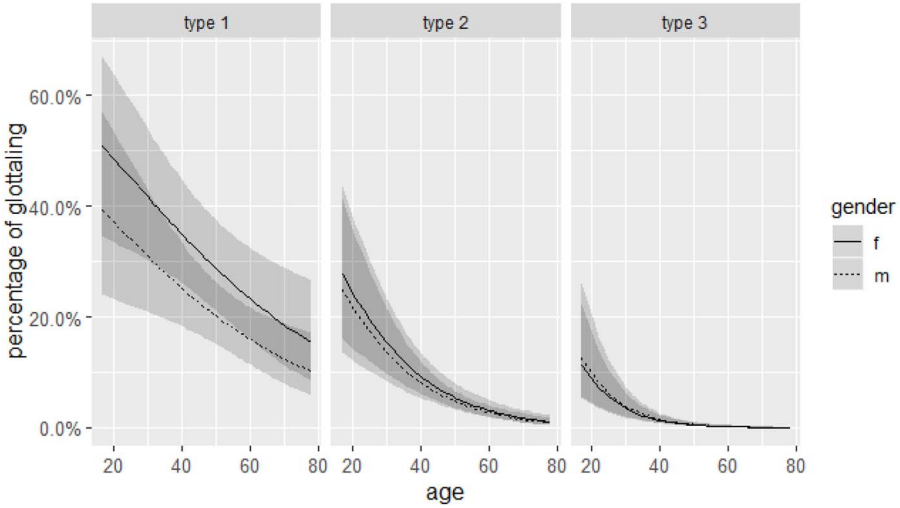

Figure 4. Effects of AGE*GENDER on the three types of T-glottaling.

six representative examples among the speakers: 58/91 speakers (about 64%) did not produce glottal stops for Type 3 at all, such as speaker s102 ($n = 46$), who realized nearly 75% of Type 1 and slightly more than half of Type 2 but none of Type 3 as glottal stops. Among the 58 speakers, three also realized [t] for Type 2 categorically like speaker s21 ($n = 134$) in Figure 6. In other words, these three speakers only produced glottal stops for Type 1 contexts but never for Type 2 or Type 3 contexts. T-glottaling for Type 1, on the other hand, was not produced exclusively for any individual.

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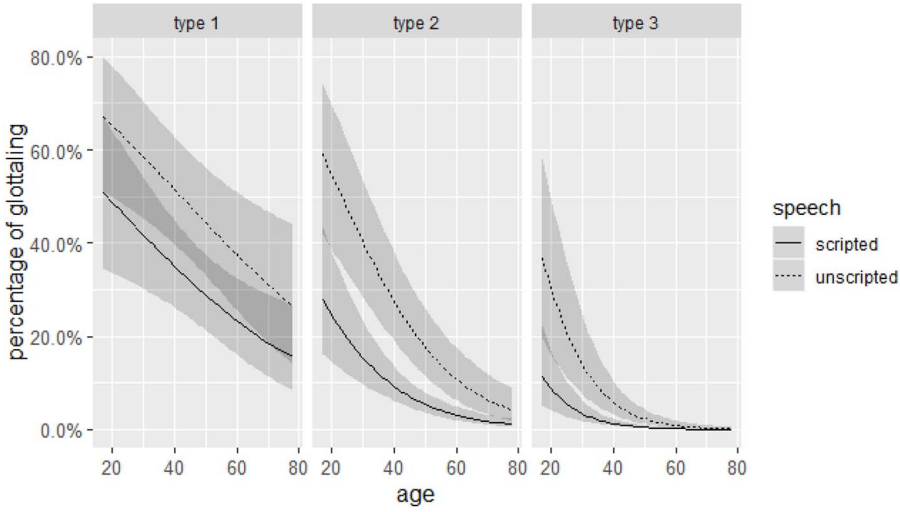

Figure 5. Effects of AGE*SPEECH STYLE on the three types of T-glottaling.

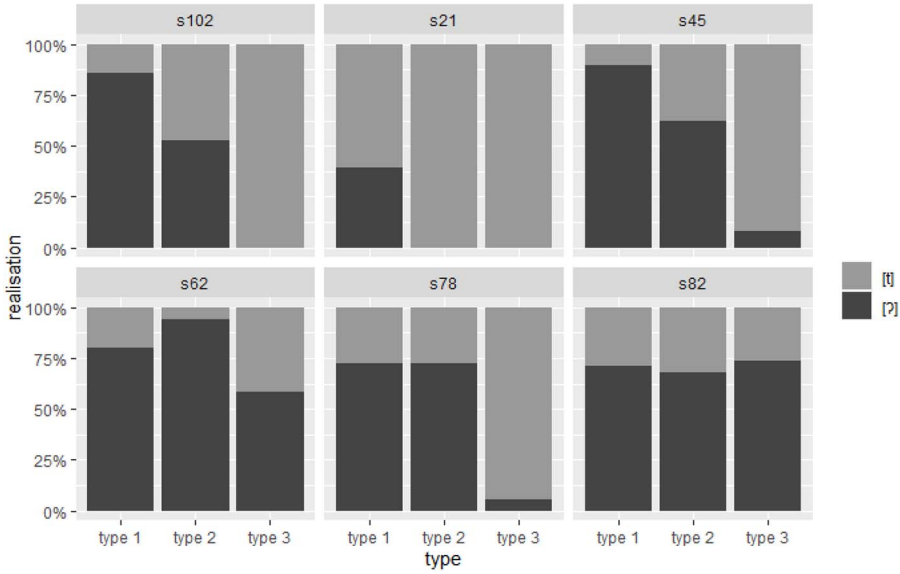

Figure 6. Individual differences in rate of T-glottaling in the three types.

As expected, most of the speakers (77/91, including the 58 speakers discussed above; about 85%) produced glottal stops with the hierarchy of Type 1 > Type 2 > Type 3, with different degrees of T-glottaling in each environment. Speaker s45 ($n = 47$), for example, realized nearly 90% of the /t/ tokens as [ʔ] for Type 1, 68% for Type 2, and only 9% for Type 3. A less prominent pattern concerns Type 2 > Type 1 > Type 3, and 12 speakers in total displayed this pattern such as speaker s62 ($n = 114$; 81% for Type

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1; 95% for Type 2; 57% for Type 3). As Figure 6 illustrates, it is also possible for some speakers to show a very similar distribution of Type 1 and Type 2 (e.g., speaker s78: $n = 62$). Speaker s82 ($n = 107$) even produced similar rates of glottal stops for all the three types, with Type 2 realization being slightly lower than for the other two types.

Discussion

The aim of this study was to explore the status of T-glottaling in present-day SSE. It constituted the first large-scale study comprising more than 130 speakers and analyzing a wide range of social and linguistic factors that potentially influence T-glottaling in this variety. The results show that about one third of the analyzed /t/ tokens are realized as a glottal stop, albeit with considerable inter-speaker and intra-speaker variability. SSE speakers produce significantly more T-glottaling in word-final than in word-medial position, which confirms findings by Hall-Lew et al. (2019), who investigated the speech of 17 famous Scottish women, as well as findings by Schleef (2013) for Edinburgh teenagers. Moreover, we found that some of the social and linguistic factors that we investigated influence the rate of T-glottaling in word-final and word-medial /t/ differently (which was also found by Schleef [2013]). This finding calls for future studies to focus on the examination of T-glottaling in those two positions separately.

For the production of both word-final and word-medial /t/ in SSE, the following phonetic context, age, and speech style were found to constrain the rate of T-glottaling. While following sonorant consonants and obstruents favor word-final T-glottaling, following vowels and pauses do not, showing the typical hierarchy of C > V > P (cf. Hall-Lew et al., 2019 for Scottish English). Thus, in this respect, SSE's diffusion pattern differs from the C > P > V found in Edinburgh speech (Schleef, 2013), British accents (Straw & Patrick, 2007), and the Buckie dialect (Smith & Holmes-Elliott, 2017), which showed the highest word-final T-glottaling before vowels. Our findings thus underline the special status of SSE as a standard variety in Scotland that is influenced by multiple norms from both within and outside of Scotland (e.g., Schützler, 2014).

As regards the word-medial position, both sonorant consonants and obstruents favor the realization of /t/ as a glottal stop in SSE, while a following vowel and syllabic liquid disfavor glottal stops. As in all other varieties of Scottish English that have been analyzed so far, T-glottaling is more likely to occur in unscripted speech than in scripted speech, and younger speakers of SSE produce [ʔ] more frequently than older speakers in both word-final and word-medial positions. We have, thus, observed an apparent time pattern which could be evidence of an ongoing language change in SSE towards more T-glottaling in future years.

The general lack of general gender differences found for T-glottaling in SSE is in line with findings on other aspects of the phonology of SSE based on the same dataset from ICE-Scotland such as the degree of rhoticity (Meer, Fuchs, Gerfer, Gut, & Li, 2021) and the realization of the NURSE vowel (Li, Gut, & Schützler, 2021). Although various language-internal and -external factors were identified in those studies that influence these phonetic/phonological realizations, gender differences were not found. Only the realization of <wh> in SSE was found to be constrained by gender, with female speakers producing a significantly higher amount of [w]-like realizations containing less friction than their male counterparts (Li & Gut, 2022). Like for T-glottaling in Type 1

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phonetic contexts, female SSE speakers appeared to take the lead in the ongoing change resulting in the merger of /ʍ/ and /w/ in SSE. Overall, however, our findings suggest that a standard variety such as SSE is less subject to variation across genders than other (non-standard) varieties.

While the following phonetic context influences the rate of T-glottaling in SSE for word-final and word-medial /t/ alike, differences regarding the impact of word type emerge. More specifically, we found that function words favor T-glottaling significantly more than content words only word-finally in SSE. The influence of word type on word-medial T-glottaling, on the other hand, did not reach statistical significance. This difference between word-final and word-medial T-glottaling in the present study might be due to an imbalance in the data. Only 280 out of 5,037 word-medial tokens in the dataset are function words, which are known to favor glottaling.

One further objective of this study was the investigation of the three types of T-glottaling in SSE that were described by Wells (1997) to have emerged and diffused in RP at different times and to a different degree. For speakers of SSE, the relative realization rates of these types that have been found in RP (Badia Barrera, 2015) were replicated: Type 1 T-glottaling (i.e., T-glottaling preceding an obstruent or a sonorant consonant both word-finally and word-medially) is most frequent, followed by Type 2 (i.e., word-final T-glottaling preceding a vowel or a pause), whereas Type 3 (i.e., word-medial T-glottaling preceding a vowel or a syllabic liquid) is extremely rare. While Type 1 was shown to occur categorically in informal speaking style for young RP speakers (Badia Barrera, 2015) and was proposed to be categorical in many British accents (Straw & Patrick, 2007), we found that, in SSE, Type 1 T-glottaling is still produced variably with different social constraints and has not yet reached categorical performance in any speech categories or among any speaker groups. This finding is further confirmed by the investigation of individual patterns of T-glottaling across SSE speakers: all speakers in the present study produced Type 1 T-glottaling to different degrees and no one has reached categorical performance yet. This indicates that in SSE the diffusion of T-glottaling seems to be slower/less complete than in other British accents such as RP, which underlines the sociolinguistic uniqueness of SSE as a localized norm spoken in a "multi-dimensional sociolinguistic variation space," as Maguire (2012:55) put it.

Moreover, Type 3 T-glottaling appears to have entered SSE only relatively recently. While T-glottaling of Types 1 and 2 is produced by speakers of all ages in our dataset, Type 3 is only used among younger speakers below the age of 40, and about 64% of the speakers did not produce Type 3 T-glottaling at all. T-glottaling of Type 2 is increasingly used in unscripted speech by young speakers of SSE (60% for 20-year olds), which might herald an upcoming spread to other speaking types and speaker groups. The occurrence of Type 3 T-glottaling is still rare in SSE, but its more frequent use in unscripted speech for young speakers suggests a possible spread in the future. The fact that gender differences between the speakers of SSE were only found to be significant in Type 1 T-glottaling can be interpreted to confirm the distinctiveness of these three processes.

Overall, the present findings confirm our hypothesis that an implicatory relationship exists between the three types of T-glottaling and that they are developing in the order of Type 1 > Type 2 > Type 3 in SSE. It is still important to note that while the

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individual patterns of most SSE speakers in the present study followed this order, some of them (12/91) displayed a different pattern of Type 2 > Type 1 > Type 3. Our findings suggest that, in future studies, these types of T-glottaling should be analyzed separately.

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Competing interests. The authors declare none.

Notes

1. We are aware that speaker class is a potential influencing factor of T-glottaling according to previous studies, and we assume that our speakers of Scottish Standard English are from a middle-class background given their occupations. However, the actual background of the speakers in the corpus is mostly unknown, and therefore the impact of class could not be examined.

2. The modelled line is not entirely straight, which we assume reflects a tendency/progression in apparent time that glottaling is much more popular in speech of younger speakers while those over 40 years seldom use the variant, especially for Type 2/3. Another possible reason is that some of the speakers' age is not given as an exact number but rather as an age range (e.g., 30–35 years) in the corpus, which might lead to an exponential-looking curved pattern.

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Appendix A

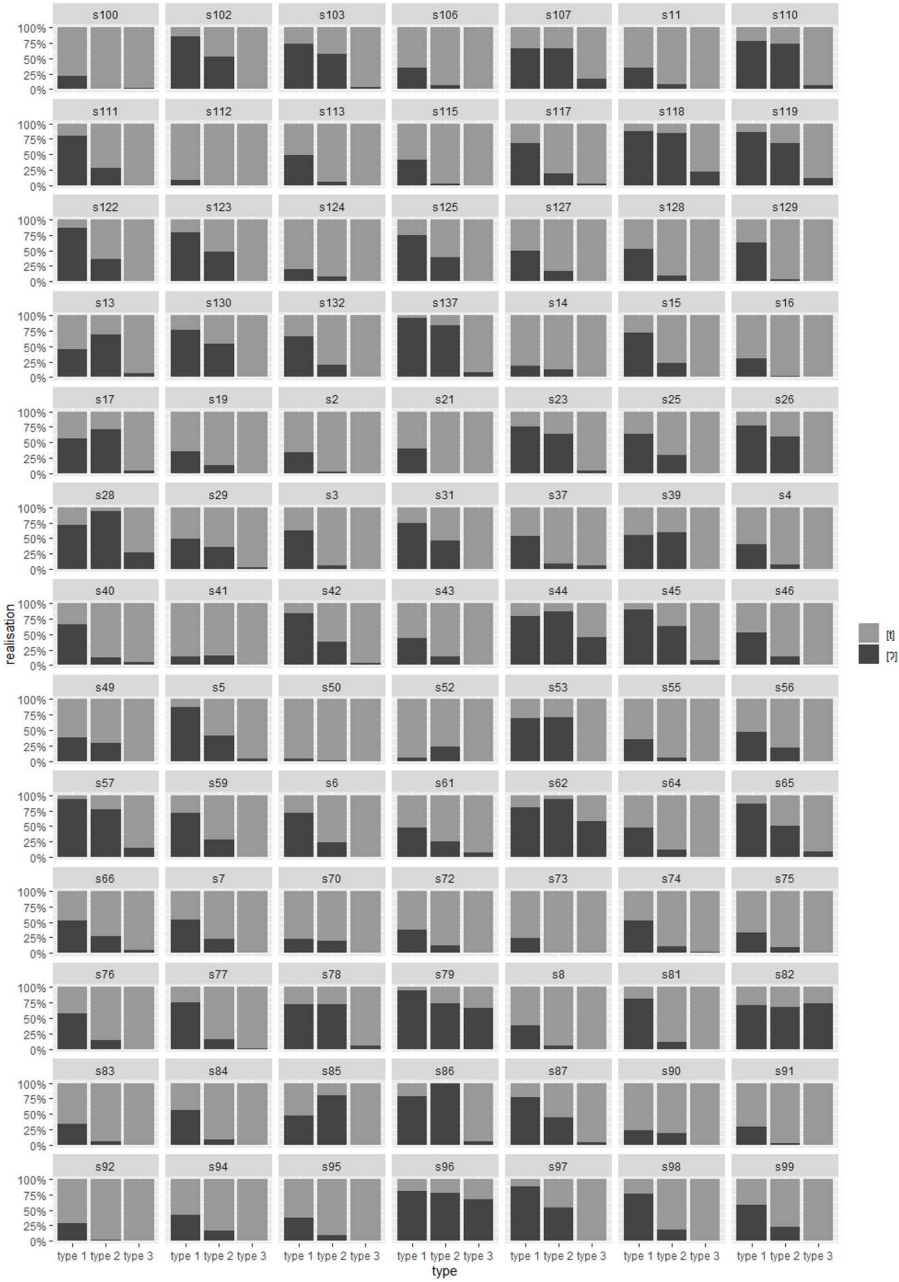

Figure A1. Individual realization of T-glottaling in the three types.

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Appendix B

Table B1. List of speakers with age, gender, and ICE-Scotland text category

Speaker	Gender	Age	Category
s100	m	25–40	Broadcast talk
s102	m	49	Broadcast discussion
s103	m	60	Broadcast interview
s106	f	73	Broadcast talk
s107	m	47	Broadcast talk
s11	f	41	Broadcast news
s110	f	40–50	Broadcast discussion
s111	f	44	Broadcast talk
s112	m	45	Broadcast news
s113	f	50–60	Broadcast talk
s115	m	78	Broadcast talk
s117	f	44	Broadcast discussion
s118	m	40+	Broadcast discussion
s119	f	34	Broadcast discussion
s122	f	48	Broadcast talk
s123	m	50+	Broadcast discussion
s124	m	60+	Unscripted speech
s125	m	52	Broadcast talk
s127	m	35–50	Broadcast talk
s128	m	40–50	Broadcast talk
s129	m	60+	Broadcast talk
s13	m	50	Broadcast interview
s130	f	60	Broadcast talk
s132	m	50+	Demonstration
s137	m	47	Broadcast discussion
s14	m	50+	Broadcast interview
s15	f	35	Broadcast interview
s16	f	63	Parliamentary debate
s17	f	43	Parliamentary debate
s19	m	40–60	Demonstration
s2	m	58	Legal presentation
s21	m	50+	Broadcast news
s23	m	58	Broadcast discussion

(*Continued*)

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Table B1. (*Continued.*)

Speaker	Gender	Age	Category
s25	m	60	Broadcast talk
s26	f	35	Unscripted speech
s28	f	69	Broadcast discussion
s29	m	54	Broadcast discussion
s3	f	21	Nonbroadcast talk
s31	f	40–50	Broadcast talk
s37	m	64	Broadcast discussion
s39	m	40+	Broadcast discussion
s4	m	70+	Nonbroadcast talk
s40	m	56	Parliamentary debate
s41	m	50–55	Broadcast interview
s42	f	52	Broadcast talk
s43	f	40–60	Broadcast talk
s44	f	18–25	Nonbroadcast talk
s45	m	25	Broadcast talk
s46	m	36	Broadcast news
s49	m	60–70	Unscripted speech
s5	f	44	Broadcast talk
s50	m	59	Nonbroadcast talk
s52	m	50–60	Broadcast news
s53	m	38	Broadcast discussion
s55	f	50–55	Broadcast talk
s56	m	62	Legal presentation
s57	m	50+	Broadcast discussion
s59	f	40–50	Broadcast talk
s6	m	63	Broadcast talk
s61	m	40–50	Broadcast discussion
s62	m	20–30	Nonbroadcast talk
s64	f	66	Broadcast talk
s65	f	17	Broadcast talk
s66	f	45–55	Nonbroadcast talk
s7	m	50+	Legal presentation
s70	m	49	Broadcast news
s72	m	50	Legal presentation
s73	m	65+	Broadcast talk
s74	m	50	Broadcast talk
s75	m	55+	Legal presentation

(*Continued*)

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Table B1. (*Continued.*)

Speaker	Gender	Age	Category
s76	m	54	Broadcast talk
s77	m	52	Broadcast talk
s78	m	50+	Broadcast discussion
s79	f	20–40	Unscripted speech
s8	m	63	Legal presentation
s81	f	44	Unscripted speech
s82	m	20–30	Demonstration
s83	f	60+	Legal presentation
s84	f	34	Broadcast news
s85	m	18–25	Nonbroadcast talk
s86	f	34	Broadcast interview
s87	f	48	Broadcast discussion
s90	m	65	Legal presentation
s91	m	63	Legal presentation
s92	m	59	Legal presentation
s94	f	40–50	Broadcast talk
s95	f	25–35	Broadcast news
s96	f	30	Broadcast interview
s97	m	64	Parliamentary debate
s98	f	63	Broadcast talk
s99	f	40–50	Broadcast talk

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