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Developmental Sequences in Second Language Phonology: Effects of Instruction on the Acquisition of Foreign sC Onsets

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This study investigates the effects of three types of instruction on the acquisition of foreign /s/-initial onset clusters (/sl/, /sn/, and /st/-sC clusters), a process characterized by a developmental sequence in which /sl/ is acquired before /sn/ and /st/. 118 native speakers of Brazilian Portuguese participated in a 4-week language course to learn a set of vocabulary and associated pronunciation of Taki, a self-constructed miniature linguistic system. The participants were divided into three groups, each corresponding to one of the hypotheses that characterize three types of explicit second language instruction: Teachability, Projection of Markedness (Projection), and a combination of the two (Mixed). A mixed analysis of variance (ANOVA) analysis of the participants' production of sC clusters revealed that, in one of the tasks employed (read aloud), the group that focused exclusively on the more marked/st/ (Projection Group) had the best overall performance in the acquisition of the three clusters: this group was able to generalize their knowledge to the sC clusters they were not taught. In general, the results support Zobl's Projection Model of Markedness for explaining the phonological development of syllable structure, wherein the instructional effect of a focus on the most marked /st/ projects to knowledge of the less marked structures.

Keywords: developmental sequences, second language phonology, syllable structure, miniature phonology, sC clusters, artificial language

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INTRODUCTION

The literature on phonological acquisition is replete with studies showing that the oral production of/ s/-initial onset clusters (sC; e.g., /st/op, /sl/eep, /sn/ow) is particularly problematic for first language acquirers (L1; Goad and Rose, 2004; Yavaş & Barlow, 2006) and second/foreign language learners (L2; Carlisle, 2006; Major, 1996).[1] Some of these studies also reveal that the acquisition of sC follows a "natural order of acquisition" or developmental sequence in which the /s/ + sonorant sequences /sl/

[1]English is used and studied in Brazil as a *foreign* language. We use the term *second* language in this paper in its broader sense of the learning of an additional language.

and /sn/ tend to appear before /st/ (Carlisle, 2006; Yavaş & Barlow, 2006; Boudaoud, 2008; Cardoso & Liakin, 2009).

From a pedagogical perspective, these studies raise an interesting question with regards to instructional intervention: Will the effects of a focus on the form that is acquired late (and assumed to be difficult) project to the forms that are usually acquired early (and assumed to be easy)? Or will the reverse lead to a more successful mastery of developmental sequences, as is often implied in the design of L2 instructional materials in which these sequences are introduced starting from the easy end of the hierarchy?

Research investigating this issue has focused on the instruction of morphosyntax and has yielded mixed findings (reviewed below). The pedagogical implementation of these ideas from an L2 phonological perspective includes suggestions that problematic L2 sounds be taught first (e.g., Eckman & Iverson, 1997; Doughty & Williams, 1999, p. 21), or *via* tasks that progress in stages from easy to more challenging (Pennington, 1999). However, to our knowledge, there has been no published research that has tested these claims (but see a pilot study by Cardoso, 2010). One of the goals of this study to address the issue from a *phonological* perspective and thus lay groundwork for future research on the acquisition of L2 phonological developmental sequences.

LITERATURE REVIEW

Natural Order of Acquisition or Developmental Sequences

The concept of a natural order of acquisition or developmental sequence characterized some of the "morpheme order" studies that propagated in the 1970s and 1980s. Influenced by Chomsky (1970) claims of a language acquisition device or Universal Grammar, many linguists were concerned with uncovering the innate knowledge that guided language acquisition by showing that learners mastered linguistic structures in the same order, regardless of the quality and quantity of input in the ambient language, or the first language in the case of L2 learning. For L1 acquisition, two of the most prominent studies are those of Brown (1983) and de Villier and de Villiers (1977), who investigated the development of English morphosyntactic features in children. They observed that the present progressive-*ing* form was the first morpheme to be acquired, followed by a set of other morphosyntactic elements (e.g., articles *the*/*a* followed by the possessive'*s*), and culminating with the mastery of contractible auxiliary forms (e.g., 's in *Daddy's eating*).

In the context of L2 acquisition, the studies by Bailey et al. (1974), Larsen-Freeman (1975), and Rosansky (1976) reported similar results confirming most of the abovementioned findings, *mutatis mutandis*. In these studies, speakers of a variety of L1s (Arabic, Farsi, Japanese and Spanish) acquired English morphosyntax obeying a developmental sequence that initiated with the present progressive-*ing*, advanced towards the articles *the*/*a*, and concluded with the possessive'*s*. Inspired by Brown (1983) hypothesis for L1 acquisition, suggestions by Corder (1967) and empirical evidence by Dulay and Burt (1978), the concept of a natural order for L2 acquisition was later formalized by Krashen (1981) in the form of the Natural Order Hypothesis (see also Ellis, 1997; Lightbown, 1980; Spada and Lightbown, 1999; Wode, 1976 for actual studies documenting developmental sequences in L2 acquisition, and Kwon, 2005 for a review of the literature on natural order morphemes).

Although not as widely investigated as in morphosyntax, developmental sequences have also been observed in L1 phonological acquisition, particularly involving the development of segments and syllable structure. For segments, for example, it is common knowledge that vowels are acquired before consonants (e.g., Jakobson, 1968; Davis and MacNeilage, 1990), and that stops are mastered before fricatives and liquids, in that order (e.g., Bernhardt and Stemberger, 1998). With regard to syllable structure, onsets have a universal tendency to be acquired before codas (e.g., Smith and Stoel-Gammon, 1983; Vihman, 1996) and, pertinent to this study, /s/ plus liquid onset clusters (/sl/) are usually mastered before /s/ plus stop sequences (e.g., Smith, 1973; Gerrits and Zumach, 2006; Yavaş and Barlow, 2006, and Hefter and Cardoso, 2010).

There is also evidence that L2 phonological development follows similar natural order patterns. For example, in the development of L2 syllable structures, learners tend to produce more errors in word-final codas than in word-initial onsets (e.g., Flege and Davidian, 1984; Cardoso, 2007). For sC onsets, as mentioned earlier, acquisition follows a developmental sequence in which /s/ plus sonorant sequences (e.g., /sl/ and /sn/) are acquired before their /s/ plus plosives counterparts such as /st/ and /sk/ (Tropf, 1987; Carlisle, 1991, 2006; Rauber, 2006; Yavaş and Barlow, 2006; Boudaoud, 2008; Cardoso & Liakin, 2009).

In sum, there is convincing empirical evidence to substantiate the claim that acquisition of certain linguistic items occurs in predictable orders. What is unclear is the extent to which instruction can affect the acquisition of items that comprise a given developmental sequence: Will tutored learners acquire structures in the order in which they are presented in instructional settings? If so, which end of the sequence should pronunciation teaching emphasize in order to become more effective?

Instruction and Developmental Sequences in Second Language Acquisition

One hypothesis is that instruction should follow the known order of acquisition; that is the design of L2 instructional materials in which these sequences are introduced from the easy end of the hierarchy. A second hypothesis postulates that a more effective use of instructional time is to target the later acquired (and thus more difficult to learn) form, based on the assumption that they will project to the forms that are usually acquired early. In this section, we review the empirical evidence in support of these two positions, all in the realm of morphosyntax.

The first hypothesis can be subsumed under the Teachability Hypothesis, proposed by Pienemann (1984, 1989, 1998), and later revised as Processability Theory (Pienemann et al., 2005;

Pienemann, 2007).[2] This hypothesis predicts that a novel linguistic form can only be acquired when learners are developmentally ready, when they "can produce and comprehend only those L2 linguistic forms that the current state of the language processor can handle" (Pienemann, 2007, p. 137), and when they are able to process the structures that will lead them to the next developmental stage (Meisel et al., 1981). Mackey and Goo (2007) demonstrated that when adult English learners from a variety of L1 backgrounds acquire question formation, only those who are developmentally ready (e.g., have acquired auxiliary inversion in yes/no questions-Stage 4) are able to make greater gains in higher level structures (i.e., acquire Wh-questions and copula inversion-Stage 5). Mackey and Philp concluded that, "If learners are not at the correct developmental level they will not acquire the structure; it is supposedly unlearnable, unteachable, and untreatable" (p. 340). L2 acquisition studies that also support this hypothesis include Bardovi-Harlig (1995-English pluperfect), Ellis (1984-English Wh-questions in children; 1989-German word order), Felix (1981-English negation, interrogation, and other morphosyntactic structures), Jensen et al. (2003) and Pienemann et al. (1988). Based on typological explanations and first language acquisition research, a common denominator among these studies is that they demonstrate that learners acquire the most common and most basic structures first, and the rare and more complex ones last, if at all.

A second proposal for the investigation of the effects of instruction in relation to the order of acquisition of particular grammatical structures is the Projection Model of Markedness, proposed by Zobl (1983, 1985). Contrary to the Teachability Hypothesis, this proposal advocates an instructional focus on more advanced or more marked structures. The prediction is that an instructional focus on these more complex forms might lead (project) to the learning of basic or less marked structures. In a study investigating the effects of different types of instruction on the L2 acquisition of Japanese relative clauses, Yabuki-Soh (2007) showed that an instructional focus on a more marked relative clause [e.g., the Japanese equivalent of "The person (whom I had a fight with)"] facilitated the learning of less marked relativization [e.g., "The person (who gave me a book)"]: learners who were taught the more marked relative clause were able to "project" that knowledge to lower-level structures and thus generalize relativization rules to simpler contexts. This hypothesis is supported by several studies, mostly involving the acquisition of relative clauses in English (Gass, 1982; Doughty, 1988, 1991; Eckman et al., 1988), French (Mitchell, 2001), and Japanese (Yabuki-Soh, 2007), or possessive determiners in English (Zobl, 1985). Interestingly, the hypothesis has also been observed in speech pathology, with research showing that the treatment of marked fricatives enhances the learning of unmarked stops (Dinnsen and Elbert, 1984), while a focus on consonant clusters leads to an overall improvement in the production of less marked singletons (Gierut, 1999; Gierut and Champion, 2001).

Finally, a third hypothesis to which we will refer as "the Mixed Approach" questions the efficacy of step-by-step teaching of specific items or features following a given developmental sequence (Shirai, 1997; Lightbown, 1998; Spada and Lightbown, 1999). Based on the scarcity of empirical evidence (i.e., all involving the acquisition of morphosyntactic features, and most with English, French or German as the target languages) and the inconclusiveness of the available studies favouring either one of the hypotheses, proponents of the Mixed Approach for teaching developmental sequences suggest that *both* more complex and less complex structures should be emphasized in instruction. This view is shared by Ammar and Lightbown (2004), who investigated the acquisition of English relative clauses by Arabic speakers and found that, regardless of the form emphasized in teaching, learners were able to generalize to the opposite end of the developmental hierarchy. These findings led the authors to conclude that combining different types of relative clauses in instruction can be as effective as starting at either end of the developmental sequence. Similarly, Shirai (1997) recommended that the instruction of natural order phenomena be conducted in a way that emphasizes exposure to both marked and unmarked structures.

Aside from a pilot study conducted by Cardoso (2010), we are not aware of any other published study that examines the effects of teaching (instructional intervention, as defined earlier) on the acquisition of developmental sequences from a phonological perspective. One of the goals of this study is to contribute to our understanding of the nature of pedagogical interventions and their effects on learning and, more importantly, to address this gap in the literature by examining, in an instructional setting, the L2 acquisition of a phonological developmental sequence: foreign onset sC clusters.

The L2 Acquisition of sC Onsets

The oral production of foreign sC onsets is notoriously difficult for learners whose first languages disallow such sequences (Major, 1996; e.g., Japanese, Portuguese, Spanish, Turkish). In the context of Brazilian Portuguese (BP) speakers learning an "sC language" such as English, French or German, for instance, learners variably syllabify the cluster *via* a prothetic (i) (i-epenthesis), thus triggering the resyllabification of the original onset into a nucleus-coda sequence (e.g., /st/op → [is.t]op). While i-epenthesis can be usually attributed to an L1 effect (sC onsets are non-existent in BP and i-epenthesis is the most commonly-employed strategy for syllabifying illicit structures; see also Cristófaro Silva and Freitas (2020), who found that sC clusters are phonetically represented as either [is. C] for native words, or [sC] for loanwords), the phenomenon is rather complex and is motivated by a variety of linguistic and extralinguistic factors (Cardoso and Liakin, 2009).

[2]Note that Processability Theory (or the Teachability Hypothesis) is a theory of L2 development that was proposed to analyse morphosyntactic structure, not phonological phenomena such as the one addressed in this study. However, the general premises of the Theory can be easily extended to the analysis of other linguistic components: 1) It involves a developmental trajectory; 2) processing components operate automatically, i.e., they are not consciously controlled; 3) processing is incremental; 4) the output of the processor is linear; and 5) processing has access to a temporary memory store that can hold grammatical information (Pienemann, 1998, 2007). The patterns observed in sC acquisition clearly satisfy these requirements, with respective differences taken into consideration.

One of these factors include the concept of sonority, defined *via* a combination of features such as amplitude or intensity (Ladefoged, 1993), acoustic energy (Goldsmith, 1989), and propensity for voicing (Kenstowicz, 1994). Together, and focusing exclusively on the set of relevant segments, these features determine a sonority hierarchy that ranges from the least sonorous stop/t/ to the more sonorous liquid /l/: /t/ </s/ </n/ </l/ (where "<" indicates "less sonorous than"). In order to constitute legitimate onset clusters, the sC combination should follow a pattern in which sonority progressively rises towards the nucleus of the syllable (Sonority Sequencing Principle-SSP, Selkirk, 1984). While both the /sl/ and /sn/ satisfy the SSP requirement because sonority rises from /s/ to the following segment, /st/ constitutes an SSP violation because sonority sequencing decreases in the second consonant. In addition, onset cluster syllabification tends to favour sequences that have a "maximal and most evenly-distributed rise in sonority" (Minimal Sonority Distance-Clements, 1990, p. 303). This preference favours the sequence /sl/, which has a wider sonority distance than /sn/. Appealing to the concept of markedness (e.g., de Lacy, 2006), one may then assume that these three sequences constitute a hierarchy in which /sl/ is the least marked, followed by /sn/ and then the most marked /st/: /sl/ </sn/ </st/ (where "<" indicates "less marked than"). The implication of this generalization based on markedness is that learners will have less difficulty in acquiring the least marked /sl/ than the more marked /sn/ and /st/ clusters.[3] Not surprisingly, this is exactly what is found in a number of studies that investigate L2 sC acquisition, as will be discussed next.

The majority of the literature on L2 sC acquisition indicates that the path to sC development initially favours unmarked segments such as /s/ + liquids, which are acquired earlier and with less difficulty than their more marked counterparts (e.g., Tropf, 1987; Carlisle, 1991, 2006; Rauber, 2006; Boudaoud, 2008; Cardoso and Liakin, 2009). In a study involving the same community of BP speakers examined in this investigation, Cardoso and Liakin (2009) found a pattern of sC development that reflects the tendency found in earlier studies. Their participants produced /sl/ and /sn/ (the difference between these two SSP-abiding clusters was not statistically significant) more accurately than the more marked /st/, similar to what is observed in L1 acquisition (e.g., Hefter and Cardoso, 2010; Yavaş and Barlow, 2006), and in the development of L2 phonologies, as discussed above.[4] Studies that contradict this order of acquisition may be explained by methodological limitations: the low number of participants (e.g., Abrahamson, 1999-one participant; Major, 1996-four participants) and the inclusion of a large number of heterorganic and complex sC clusters such as /sp/, /skr/, and /spr/ (Escartin, 2005). Two additional factors that may also play a role include L1 transfer phenomena (e.g., devoicing of epenthetic [i] in Brazilian Portuguese, which leads to a misinterpretation of [isC] as target-like [sC]-Major, 1996); 2); and frequency effects in the L2 input (e.g., Escartin, 2005 maintains that the unexpected low performance in /s/ + liquid sequences was possibly due to the low frequency of these cluster types in English). Both of these factors have recently received research attention in the literature on the development of morphosyntax (e.g., Luk and Shirai, 2009 on L1 influence on the L2 acquisition order of grammatical morphemes; Collins et al., 2009 on the interaction between input frequency and tense-aspect acquisition).

The insights provided from markedness theory on sC syllabification and the empirical evidence just discussed allow us to substantiate the claim that the acquisition of these clusters is characterized by the following developmental sequence (where ">>" indicates "acquired before" and "(>>)" suggests an inconclusive but well-motivated pattern based on markedness and some previous studies): /sl/ (>>) /sn/ >> /st/.

A review of the literature also reveals some confounding factors that may interfere in the acquisition of sC. Firstly, some of these studies suggest that the heterorganicity of the onset constituents might have an effect on the production of sC (Boudaoud, 2008; Cardoso and Liakin, 2009). For instance, while the /s/ + nasal /sn/ and /sm/ clusters are equally marked with respect to sonority sequencing, as discussed earlier, they differ in place of articulation (while /sn/ is comprised of two coronal segments, /sm/ contains the coronal and labial articulators). Considering Clements' (1990) Sequential Markedness Principle ("For any two segments A and B and any given context X_Y, if A is simpler than B, then XAY is simpler than XBY"; p. 313) and the fact that the coronal /n/ is less marked than the labial /m/ (Prince and Smolensky, 2004), it follows that the /sm/ sequence is the

[3]Using L1 data from West Germanic languages and based on an analysis that considers/s/ in sC clusters an Appendix constituent (i.e., the segment is directly linked to the syllable node, thus overpassing the Onset), Goad and Rose (2004) conclude that these sequences correspond to what UG provides as unmarked, thus contradicting our assumption of a markedness relationship between the three clusters. The authors acknowledge, however, that the Appendix and consequently the unmarked analysis for sC clusters "is often not well accepted" (p. 123), and this is particularly the case in the L2 literature (e.g., Carlisle, 1991, 2006; Major, 1996, 2001; Cardoso and Liakin, 2009). Other less orthodox proposals for sC representation include the assignment of/s/ as the first member of a complex segment (e.g., Selkirk, 1982) or as an adjunct to the syllable (Barlow, 2001). Along the lines of Boyd (2006) and based on robust empirical evidence from L1 and L2 acquisition studies, we assume the standard view that no structural distinction exists between sC and other complex onset cluster and, accordingly, that there exists a markedness relationship between the segments that comprise the sC set, as established in this paper.

[4]One could also argue that the frequency of epenthesized forms of sC in the L1 Brazilian Portuguese could also affect its acquisition (e.g., the high frequency of [is.t] vis-à-vis [is.n] and [is.l] in BP could lead learners to have more difficulty in acquiring the target [st] sequence). While this seems to be a valid hypothesis, we believe that the issue is more complex than what is implied here. For instance, while the described L1 effect could be argued for production (Cardoso and Liakin, 2009; i.e., the [ist] cluster is indeed more frequent in BP, which might hinder the acquisition of the target [st] form), it would not hold for perception, since the target [st] has a higher propensity to be perceived accurately than the other clusters (Cardoso et al., 2009). The effects of the L1 on different types of sC instruction are being addressed by a larger program of research by some of the authors.

most marked of the two clusters and, consequently, more likely to be acquired last.[5] Motivated by the Sequential Markedness Principle and the allegation that heterorganicity may affect sC development, this study will focus exclusively on the acquisition of the homorganic sC clusters /sl/, /sn/ and /st/.

Secondly, some of these studies allude to the fact that the frequency with which the sC structures occurs in the L2 input might also affect their acquisition (Escartin, 2005; but see Cardoso and Liakin, 2009 for evidence to the contrary). This analysis is based on the assumption that the productivity of a pattern is determined by its type and/or lexical frequency: "the more items (are) encompassed by a schema, the stronger it is, and the more available it is for application to new items" (Bybee, 2001, p. 13; see also Archibald and Libben, 1995 and Trofimovich et al., 2007 for similar claims).

Finally, it is possible that some of the divergences found in previous research could be attributed to the type of instruction that the participants received when learning the target language. The studies consulted, for instance, provide no information about the characteristics of the teaching environment, particularly on whether the production and perception of sC received any instructional focus in the classroom and, if that was the case, on how pronunciation was taught. One could presume, for instance, that a given group of participants produced the most difficult /s/ + stop sequences more accurately simply because these learners took part in pronunciation activities that targeted this form. Being the most frequent sC structure in English (/st/ occurs in over 87% of all sC forms found in a student-directed teacher talk corpus-Cardoso and Liakin, 2009), an imbalanced focus on /st/ is unavoidable in any pronunciation activity containing the cluster. Information about the type of instructional exposure is also important because techniques such as corrective feedback can enhance L2 learning (Lyster and Saito, 2010).

In sum, any study investigating the effects of types of instruction on the L2 acquisition of sC should take into consideration the confounding factors of heterorganicity within the cluster, the frequency distribution of the relevant structures in the target L2, and the types of instruction to which learners have been exposed. While the place of articulation confound can be easily addressed by confining the set of learnable targets to coronal plus coronal sequences such as /sl/, /sn/, and /st/, the target L2 input and the type (and quality) of previously experienced pedagogical interventions cannot be reliably controlled in a standard language classroom. To address these limitations, this study adopts a miniature linguistic system (MLS), Taki, an artificial language designed to allow for control of the input participants encounter.

[5]Obviously, the homorganic sC clusters violate a phonotactic constraint against homorganicity (the Obligatory Contour Principle for Place: Adjacent identical place features are prohibited; Carlisle, 2006; Barlow, 2001; Goad and Rose, 2004), which is strongly operative in English as the following unattested sequences illustrate: *dl, *tl, *pw, *fw. The three target sC clusters are equally marked regarding this constraint, with sonority being the only variable feature.

Adopting a Miniature Linguistic System

In research conducted with natural language, variables that are difficult to control and/or determine include the distribution of target forms in the input, participants' previous experience with the L2 and their level of proficiency, and the quality and quantity of previous instruction). A number of SLA scholars have outlined the potential contributions of an MLS to control and manipulate key variables (Cook, 1988; VanPatten, 1990; DeKeyser, 1995; Ellis and Schmidt, 1997; Hulstijn, 1997; see also the articles in a 1997 special issue of *Studies in Second Language Acquisition* on laboratory research methods). We designed Taki (described below) to investigate sC learning, as it allowed us 1) to control the language to be learned so that the target input could be easily manipulated (quantitatively and qualitatively) to accommodate the demands of our study; 2) to guarantee that no participants in the experiment would have advanced knowledge of the target structures; and 3) to ensure that all participants received the same type of instruction in which only the order of sC presentation is manipulated, as predicted by our research questions. The adoption of an MLS thus increases the reliability of our study due to the control over the target language and the instructional environment. However, we are aware that the use of an MLS does raise ecological validity issues, and the interpretation of the findings must also consider potential limitations to the teaching and learning of natural languages. We return to these points in the discussion of the results.

This Study

The purpose of the present study is to explore the effects of three types of exposure (to which we also refer as instruction) on the development of foreign sC onsets and, at the same time, to observe how these same clusters are acquired at the end of a series of instructional interventions. This study's research question is thus formulated as follows:

- How do the three types of exposure (instructional treatment) affect the L2 acquisition of sC clusters in production? Specifically, which type of instruction is more effective for the teaching of sC clusters?

It remains difficult to predict outcomes based on the existing literature on L2 instruction and phonological developmental sequences, as it is non-existent. In addiction, the findings from the studies of morphosyntax have yielded contradictory findings.

Table 1 summarizes the three hypotheses entertained by the current study and their respective rationale, accompanied by the teaching order that they advocate (where ">" indicates "should be taught before" and "=" means "should be taught together with"):

METHOD

Participants and Experimental Groups

Hundred-eighty seven participants were initially recruited to participate in the study. However, due to previous formal learning experience with an sC language (e.g., English, French, German) or familiarity with the target structure (detected *via* the

TABLE 1 | Developmental sequences and teaching: Hypotheses and advocated teaching order.

Hypothesis	Rationale	Teaching order advocated
1. Teachability	Easy evolves to hard	sl > sn > st
2. Projection model of markedness	Hard projects to easy	st
3. Mixed	Contra step-by-step	st = sn = sl

pretest), 18 participants were excluded from the pool of potential participants. For personal reasons, 51 other participants left the experiment without completing one or more of the teaching sessions or tests. The remaining 118 were primary and secondary students with ages ranging from 11 to 22 (Mean = 14.4 years old), enrolled in two public school in the city of Belém (Brazil), a community of primarily monolingual Portuguese speakers. The participants were all monolingual native speakers of Portuguese, without any previous oral experience with an sC language. The 118 participants were randomly assigned to one of the three experimental groups, each constituting an intact class: The Projection of Markedness Group (P Group; *N* = 38), the Teachability Group (T Group; *N* = 38) and the Mixed Group (M Group; *N* = 42).

As part of the school curriculum in Brazil, students have compulsory weekly 1.5-h English classes that focus exclusively on the acquisition of morphosyntax (grammar) and translation skills (Lopes, 1996; Izidro, 2007), and sometimes on receptive (written) vocabulary and reading comprehension in order to fulfill the requirements for high-stakes exams such as the "vestibular" (a competitive nationwide examination that selects students for entry into a university program). In these typically very large classes (40–60 students), oral interactions in English are rare (Lima et al., 2014). Participants had thus had very limited exposure to spoken English.[6]

Research Design

The study employed a quasi-experimental, within groups pretest/posttest design. To examine the development of sC acquisition, it included a pretest (to measure the participants' initial knowledge of sC in oral production), an immediate posttest (week 4) and a delayed posttest (conducted 1 week after the last pedagogical intervention which, according to standards from Form-Focused Instruction research, could be classified as a "short-delayed posttest"; Spada and Tomita, 2010). The experiment lasted 4 weeks (not including the delayed posttest) and consisted of three teaching sessions (the grey area in **Figure 1**), each designed according to the three types of instruction considered in the study: While P Group was taught exclusively /st/-initial words, T Group was taught one sC per session (/sl/ > /sn/ > /st/), following their natural order of acquisition. Finally, M Group was taught all three sC sequences throughout the duration of the Taki course. The research design adopted in this study is illustrated in **Figure 1**.

Procedure

Materials: Target of Instruction and Tests

The teaching and testing materials used in this study consisted of 162 target sC-initial words and 48 distractors, equally divided among the clusters, created using WordGenerator 1.9 (http://billposer.org/Software/WordGenerator.html), a computer application that generates hypothetical words based on designated specifications such as segmental content, syllable structure and word size. To ensure that the only the learnable structure was the target sC cluster and that all remaining structures were of easy articulation, a number of phonetic, phonological, orthographic, morphological and semantic criteria were obeyed in the design of the Taki words (in the examples, "." defines syllable boundaries and "'" indicates stress):

1. Word size: words were all disyllabic (e.g. ['sle.gak] "hat" ['sta.mik] "dress"), based on the observation that dissyllabic structures are unmarked and, consequently, more easily acquired (Broselow, Chen, & Wang, 1998).
2. Foot structure (stress): trochaic, stressed on the leftmost syllable as is the case for English sC-initial words (e.g. ['snu.pak] "bird" ['sti,kab] "tie"), and following the "trochaic bias" proposed for language acquisition (Allen and Hawkins, 1978; Adam and Bat-El, 2009; but see Rose and Champdoizeau, 2007 for an opposing view on this bias).
3. Skeletal (syllabic) structure: sCV.CVC [e.g. ('sta.nud) "train" ('sla.pid) "watch"], due to the requirements of the experiment. Word-final consonants were included for another study targeting coda acquisition and, accordingly, they will not be discussed in this paper.
4. Segmental content: five vowels [(a e i o u)] and thirteen consonants [(p t k g b d f v s z m n l)] were utilized, all considered segments of easy articulation in the participants' L1.
5. Morphology: words were devoid of superfluous inflectional or derivational morphology (they were simple, uninflected words).
6. Orthography: words followed strict one-to-one grapheme-to-phoneme associations (no digraphs and diacritics were employed), based on the effects that L2 sound-to-spelling mismatches may have on vocabulary acquisition (Ludwig, 1984; Nation, 1990).

[6]In Brazil, it is widely accepted that "[private] language courses seem to constitute the only environment where one is likely to learn the English language" (Gasparini, 2005, p. 159; translation from Portuguese; see also Izidro, 2007 and Lopes, 1996 for similar claims). While this is especially true of the public-school system, it is also a characteristic of most private schools. The reasons for this situation include: pedagogical goals that are unattainable (e.g., teaching the four language skills; Lopes, 1996), large class sizes (Gasparini, 2005), limited class time dedicated to language teaching (Izidro, 2007), the teachers' low proficiency in English and limited knowledge of current L2 pedagogy (Gasparini, 2005), and possibly the pressure of lobby groups in a country where language courses are considered excellent business investments.

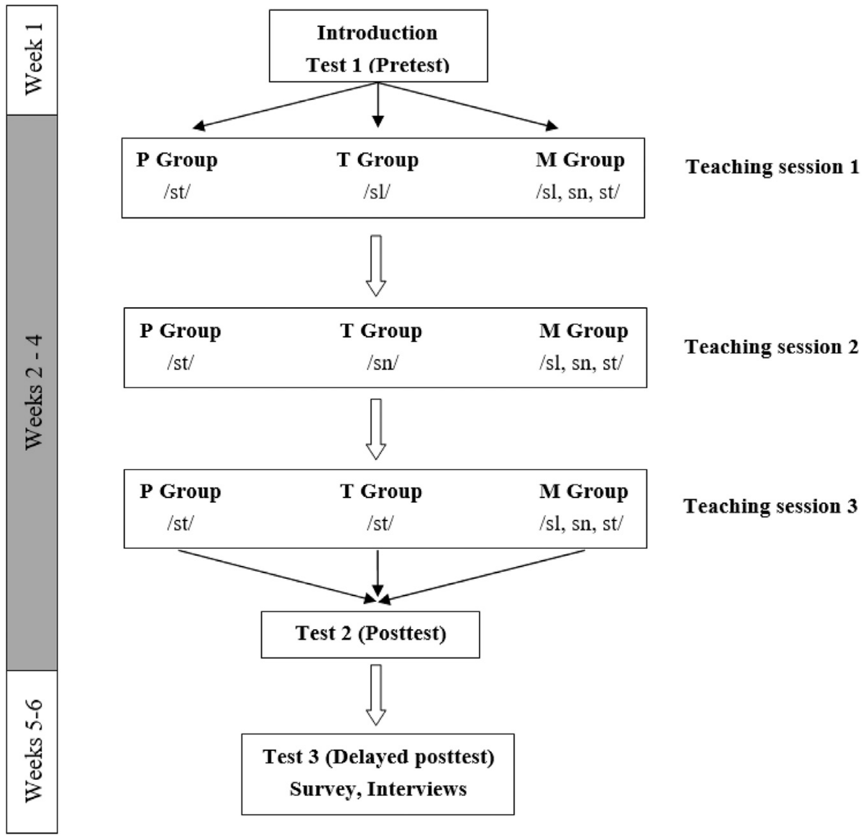

FIGURE 1 | Research design.

7. Semantic content: words were assigned to specific meanings randomly and consisted of concrete and unambiguous nouns. This decision was based on Thornbury (2002) claim that concrete meanings are more easily acquired and less susceptible to forgetting (see also Nation, 1990 and de Groot and Keijzer (2000) for similar claims). It is also in agreement with MacWhinney (1983) and Moeser and Bregman (1973) findings suggesting that words in miniature linguistic systems are better learned when the communicative context is maximized by explicit referential content.

In sum, the abovementioned criteria were motivated by attempts to manipulate only the relevant foreign sC onset and to minimize the influence of potential extraneous factors such as semantic or morphological complexity. For a complete list of the Taki words used in the three tests administered, see **Supplementary Appendix A**.

Treatment

The Taki teaching sessions were taught by the first author, a speaker of Brazilian Portuguese who has native-like oral fluency in the language (e.g., he can pronounce the target sC clusters). On the first day of class, the participants were told that, within the period of a month, they were going to learn some words from Taki, "a language especially designed to answer some questions about learning foreign languages." The weekly instructional sessions were conducted in a standard classroom in the school premises and lasted 45 min each, for a total of approximately 2 h and 15 min of Taki instruction. While this proposed learning phase seems short, it is considerably longer than most MLS-based studies (usually lasting between a few minutes and 1 h-Hulstijn, 1997, p. 138), and it falls within Norris and Ortega (2000) classification as a treatment of "medium" duration (see also Lyster and Saito, 2010).[7]

The teaching sessions, conducted in the participants'native language (Portuguese), focused exclusively on the learning of vocabulary and related pronunciation. During the introduction session (week 1) and before each class, participants were

[7]In a case study investigating the effects of a computer-based perceptual training on the acquisition of a large set of /s/ plus consonant onsets, Bettoni and Koerich (2009) found that in approximately 7 h of perceptual training, their participant was able to significantly improve her perception and production of sC for trained and unfamiliar words, in both immediate and delayed posttests.

reminded that they had to pay attention to what each new word means (semantics), how it is spelled (orthography), how it sounds (aural perception), and how it is pronounced (oral production). Briefly, the sessions consisted of the following teaching strategies (based on Thornbury, 2002 recommendations for teaching vocabulary and associated word knowledge):

1. Introduction of the word *via* an Open Office Impress slide projected on a screen with a picture and its associated sC word (See **Supplementary Appendix B** for a sample).
2. Pronunciation practice *via* the listening and oral production of the target word (either by orally imitating the instructor or reading it from the screen), followed by choral repetitions.
3. Personalized practice, so that learners could relate the word being learned to personal experiences (e.g., "[stovap], I use it to listen to music"). Whenever necessary (e.g., when the instructor heard students mispronouncing a given word), the instructor provided general explicit feedback by, for instance, repeating the target form (for the rationale, see Lyster and Saito, 2010).
4. Word retrieval activities such as picture naming ("what do you see in the picture?"), fill-in the blanks ("write what you see"), oral translations ("what's the word in Taki for "hand"?"), cross-word puzzles ("translate the Portuguese words into Taki to complete the puzzle"), and bingos ("listen and mark the word you heard on the scorecard").

Whenever possible, an attempt was made to present and discuss the sC words in preceding pausal environments (e.g., "[slovab], this is the word for hand in Taki") to prevent them from being lost *via* resyllabification [e.g., in natural speech, /a slovab/ will be produced as [as.lo.vab] "the hand", where the original /sl/ onset sequence re-syllabifies as a coda-onset cluster]. Finally, to reduce the effects of type/token frequency distribution in the L2 input, the amount of oral and visual exposure to each sC word was carefully monitored so that the participants received the same quantity and quality of treatment across the three experimental groups.

Measures: Data Collection and Assessing sC Production

To test the participants' developing "proficiency" in Taki, the study included two oral production tests, both targeting words in a context-free, pause-initial environment to ensure that the sC sequence remains intact and to mitigate preceding environment effects (see Carlisle, 1991 and Major, 1996 for evidence that the preceding word-final segment influences the frequency of prothesis before sC onsets). The two production tests were: 1) *Read aloud*, in which participants were presented a Taki word with its corresponding image on a Impress slide (e.g., snumid "violin") and asked to read it aloud; and 2) *Listen and Repeat* in a carrier phrase, in which the participants listened to the researcher and repeated what they heard in a pause-initial carrier phrase "____, mi vedu" ("____, I see"). Each test consisted of 18 target sC-initial words (six of each sC type) and six non sC-initial (the latter were used as distractors; see **Supplementary Appendix A**).

The production tests were audio recorded *en masse*, with each participant holding a mobile, hand-held audio-recorder (Sony ICD-CDUX522). The data collected were then transcribed and coded independently by two research assistants, both native speakers of an sC language.

Accurate sC production was calculated by examining only the relevant sC form for each participant and, consequently, the remaining syllabic structures and segmental content were ignored. The target sC forms were scored as either correct (e.g., if the participant produced the cluster in a target-like manner, without a preceding or following epenthetic vowel [i] ['slu.mid] "violin") or incorrect (e.g., if the target form was produced preceded or followed by [i]-epenthesis, *[is.'lu.mid] or *[si.'lu.mid] respectively, or deleted *['lu-mid]). Cases of L1-influenced /s/ palatalization (e.g [iʃ.'ti.mut]) or /t/ affrication (e.g [is.'ʧi.mut] [iʃ.'ʧi.mut]) were deemed incorrect (all instances of /s/ palatalization or /t/ affrication consisted of /i/-epenthesized sC forms). Other incorrect (but possibly developmental) variants of the target pronunciation were coded as incorrect, but due to their relative infrequency in the corpus, they were noted in the transcription for further qualitative analyses in future research (e.g., /s/ lengthening [s:. 'lu.mid] and/or /i/-devoicing; sC substitution [ka.'kub]). In case of disparity of analysis among the two research assistants (1,210 out of 6,372 tokens = 19%, or 81% inter-rater reliability), accuracy was determined by one of the researchers, sometimes with the aid of spectrographic analyses *via* Praat (Boersma and Weenink, 2019).

The total score for each participant was determined by a calculation of the number of correct production in each test, for each of the type of sC clusters considered in the study (i.e., /st/, /sn/ and /sl). In sum, all instances of sC clusters were coded according to their accuracy in production, as well as the following independent variables: type of sC cluster (/sl/, /sn/, /st/), Test (1, 2, 3), and Instructional Group (P = Projection, T = Teachability, M = Mixed). A mixed between-within subjects analysis of variance (ANOVA) was used to calculate differences between the independent variables included in the investigation.

RESULTS

The general descriptive statistics of the analysis appears in **Tables 2**, **3**, with some of the relevant results plotted in **Figures 2**, **3**. The tables present the mean scores of the 118 participants' accurate sC production in two tests (*Read Aloud*-**Table 2**; *Listen and Repeat*-**Table 3**), across the three experimental groups: P (n = 38), T (n = 38) and M (n = 42), assessed at three points in time (pretest, posttest, delayed posttest). As indicated earlier, six tokens of each target sC cluster were produced per participant per test. Considering the number of dependent variables, six mixed ANOVA tests were required, with a Bonferroni adjustment to alpha = 0.0083. To verify the homogeneity and sphericity of the data, Levene's, Box's and Mauchly's tests were used.

The results revealed a Time*Group interaction for each sC cluster, indicating that the experimental groups had an overall

TABLE 2 | Descriptive statistics for sC production over time, across three experimental groups (Mean scores) in Read Aloud test.

Test	P group						T group						M group					
	sl (*n* = 6)		sn (*n* = 6)		st (*n* = 6)		sl (*n* = 6)		sn (*n* = 6)		st (*n* = 6)		sl (*n* = 6)		sn (*n* = 6)		st (*n* = 6)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	0.68	1.23	0.32	0.784	0.82	1.52	0.34	0.63	0.08	0.27	0.66	1.07	0.36	1.08	0.12	0.39	0.62	1.06
2	3.61	2.07	2.84	1.95	3.97	1.96	1.32	1.78	1.34	1.59	2.24	1.64	1.36	1.80	1.36	1.86	2.50	2.09
3	3.34	2.16	3.11	2.20	3.92	2.00	1.61	1.64	1.53	1.84	2.42	1.98	2.50	2.09	1.98	1.96	2.40	1.85

TABLE 3 | Descriptive statistics for sC production over time, across three experimental groups (Mean scores) in Listen and Repeat test.

Test	P group						T group						M group					
	sl (*n* = 6)		sn (*n* = 6)		st (*n* = 6)		sl (*n* = 6)		sn (*n* = 6)		st (*n* = 6)		sl (*n* = 6)		sn (*n* = 6)		st (*n* = 6)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	0.61	0.88	0.58	0.92	1.13	1.63	0.53	1.03	0.47	0.76	1.63	1.65	0.67	1.30	0.60	1.08	1.31	1.92
2	2.37	1.84	2.39	2.05	2.92	1.84	1.84	1.70	1.37	1.60	3.08	2.15	1.48	2.01	1.33	1.92	2.50	2.19
3	1.89	1.74	1.95	1.96	3.11	2.09	1.92	1.87	1.92	1.75	2.37	2.10	2.38	1.75	1.95	1.85	2.98	2.19

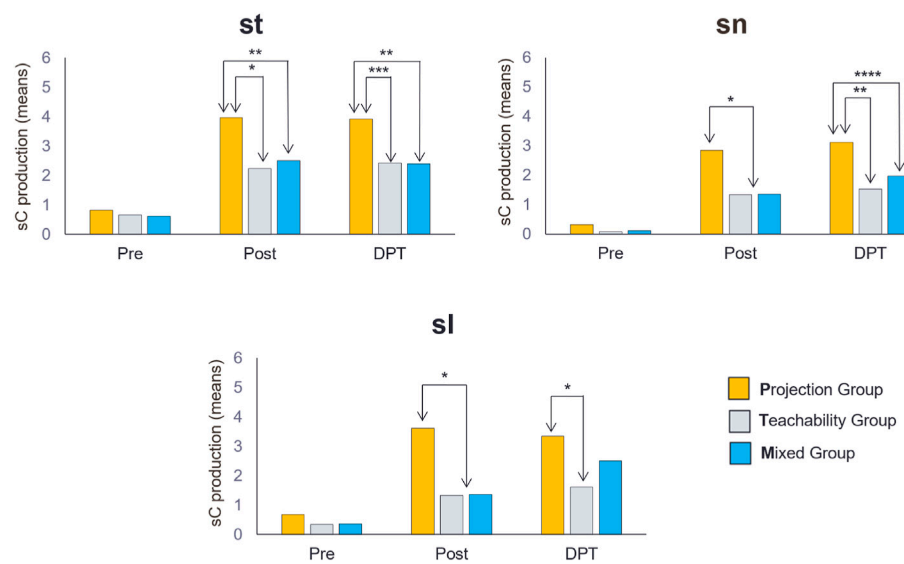

FIGURE 2 | Group Means on Read Aloud Test Over Time. Note. Significance: * $p < 0.001$; ** $p = 0.002$; *** $p = 0.003$; **** $p = 0.040$.

positive impact in the teaching of the target clusters. There were no between-group differences within sC clusters for both *Read Aloud* and *Listen and Repeat*, $F(2, 115) = 1.36$, $p > 0.05$, signaling that all clusters behaved in a similar manner across the two tests; e.g., the participants' performance improved over time across the tests, from pretest ($M = 0.44$, $SD = 0.91$) to posttest ($M = 2.26$, $SD = 2.03$) and delayed posttest ($M = 2.52$, $SD = 2.07$). Mauchly's test specified that the assumption of sphericity was violated for T Group; χ^2 (2) = 12.20, $p = 0.002$, so to gain a valid *F*-value, the Greenhouse-Geisser correction test was applied ($p = 0.004$). For *p* Group, however, the assumption of sphericity was met; χ^2 (2) = 0.56, $p > 0.05$, and AT; χ^2 (2) = 5.95, $p = 0.05$, suggesting that there were differences among the sC forms within P Group and M Group at the pretest. Because of these differences, the statistical analyses that follow will focus on Time*Group interactions for each sC cluster.

Results: *Read Aloud* Test

/st/

For /st/, a statistically significant interaction was found between the three groups and time of testing, $F(4, 230) = 4.60$, $p = 0.001$, partial $\eta^2 = 0.074$. The results of the between-subjects effects

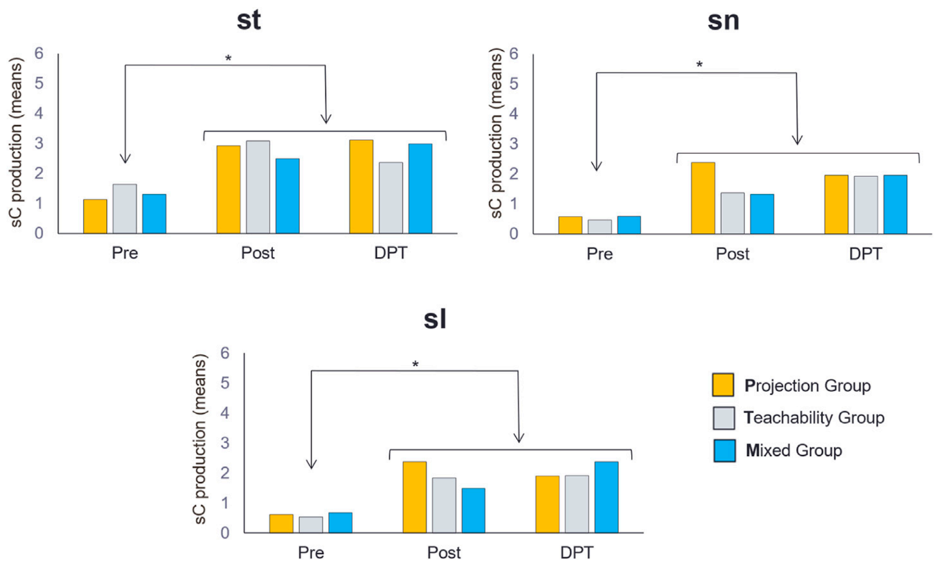

FIGURE 3 | Group Means on Listen and Repeat Test Over Time. Note. Significance: * $p < 0.001$.

ANOVA indicated that there was significant variation in /st/ production between the groups, $F(2, 115) = 8.77$, $p < 0.001$, partial $\eta^2 = 0.132$. At pretest, the Bonferroni *post-hoc* analysis indicated that there was no statistically significant effect of group between the pairwise comparisons ($p > 0.05$). However, at the posttest and delayed posttest, a statistically significant effect was observed for P Group ($p < 0.005$), in comparison with the other two groups. Pairwise comparisons of T Group and M Group were not significant at the post-and delayed post-test ($p > 0.05$).

/sn/

There was a statistically significant interaction between the three groups and time of testing for /sn/, $F(4, 230) = 4.09$, $p = 0.003$, partial $\eta^2 = 0.067$. The results of the between-subjects effects ANOVA indicated that there was a significant difference in /sn/ production between the three groups, $F(2, 115) = 9.71$, $p < 0.001$, partial $\eta^2 = 0.144$. According to the Bonferroni *post-hoc* analysis, there was no statistically significant group effect between the pairwise comparisons at the pre-test ($p > 0.05$). At the posttest and delayed posttest, however, P Group significantly outperformed both T Group ($p = 0.001$) and M Group ($p < 0.05$). Pairwise comparisons of T Group and M Group were not significant at both the post-and delayed posttest ($p > 0.05$).

/sl/

A statistically significant interaction was observed between the groups and the tests for this cluster, $F(3.883, 223.246) = 7.91$, $p < 0.001$, partial $\eta^2 = 0.121$. According to the analysis of between-subjects effects ANOVA, a significant difference was also observed between the three groups, $F(2, 115) = 13.99$, $p < 0.001$, partial $\eta^2 = 0.196$. At the pretest, Bonferroni *post-hoc* analysis revealed no significant differences in /sl/ production between the groups ($p > 0.05$). However, at the posttest, P Group outperformed both T Group and M Group (both $p < 0.001$). At the delayed posttest, P Group outperformed T Group ($p < 0.05$), but not M Group ($p = 0.184$). Pairwise comparisons of T Group and M Group were not statistically significant at the post-and delayed posttest ($p > 0.05$).

Results: *Listen and Repeat* Tests

/st/

A statistically significant interaction between the three groups and the tests was observed, $F(4, 230) = 2.86$, $p = 0.024$, partial $\eta^2 = 0.047$. However, the results of the between-subjects effects ANOVA revealed no significant difference between the participants' /st/ production and the experimental groups, $F(2, 115) = 0.066$, $p = 0.936$, partial $\eta^2 = 0.001$.

/sn/

For /sn/, there was a statistically significant interaction between the three groups and tests, $F(4, 230) = 2.91$, $p = 0.022$, partial $\eta^2 = 0.048$. The results of the between-subjects effects ANOVA, however, suggested that there was no significant difference between the three groups, $F(2, 115) = 1.108$, $p = 0.334$, partial $\eta^2 = 0.019$.

/sl/

Finally, we observed a statistically significant interaction between the experimental groups and tests, $F(4, 230) = 3.40$, $p = 0.010$, partial $\eta^2 = 0.056$. Based on the result of the between-subjects effects ANOVA, however, no significant difference between the three groups was observed, $F(2, 115) = 0.221$, $p = 0.802$, partial $\eta^2 = 0.004$.

Results: Summary

Overall, participants in all groups improved their production of sC clusters, and the observed improvement was maintained over time. Regarding the effects of different types of instruction, the findings can be divided into two categories, based on the tests adopted to assess learning.

In *Read Aloud*, the group that received instruction on the most marked /st/ (P Group) had the best overall performance in comparison with the other experimental groups (T Group and M Groups), on all sC clusters, as predicted by the Projection Model of Markedness Hypothesis. A visual representation of these findings is shown in **Figure 2**.

In *Listen and Repeat*, on the other hand, no group effects were observed, indicating that all groups equally improved on all sC clusters over time. Interestingly, the group that was taught only one single sC (/st/, P Group) had similar performance to the other groups on the two clusters that they were never taught or had a chance to practice. **Figure 2** illustrates the results obtained in the *Listen and Repeat* test, in which the three experimental groups performed similarly.

Overall, these findings indicate that, for the phonological developmental sequence under consideration, instruction that emphasizes the most marked, harder-to-acquire form is more effective for the teaching of sC clusters: the group (P) that was taught the most marked /st/ form was able to generalize the acquired structure to other less marked forms, /sn/ and /sl/. In addition, they outperformed the other two groups on the Read-Aloud task.

DISCUSSION

The goal of this study was to examine the effects of three types of instruction on the development of foreign homorganic sC onsets (/st/, /sn/, /sl/), considering three hypotheses for the teaching of items characterized by a "natural order of acquisition." Overall, the findings reported yield support for Zobl's (1993) Projection Model of Markedness inasmuch as the group that was taught the more marked /st/ (P Group) achieved the best overall results in the production of the three sC clusters in one of the tests, *Read Aloud*, and performed as well as the other groups on clusters they were not taught. These patterns are exactly what the Projection Model of Markedness predicts for linguistic items that are implicationally related in acquisition: the instructional effects of mastering the most marked /st/ cluster projects to the acquisition of the less marked forms /sl/ and /sn/. Despite the dearth of evidence demonstrating similar effects on phonological developmental sequences, our findings have parallels in the morphosyntactic literature, as will be discussed next.

The majority of the studies that corroborate the Projection Model of Markedness hypothesis involve the acquisition of either relative clauses (e.g., Doughty, 1981, 1991; Eckman et al., 1988; Gass, 1997; Mitchell, 2001, Yabuki-Soh, 2007-but see Ammar & Lightbown, 2004 for mixed results, as discussed earlier) or possessive determiners (e.g., Zobl, 1985). In contrast, the studies supporting the Teachability Hypothesis typically focus on the acquisition of distinct morphosyntactic features such as question formation (e.g., Felix, 1981; Ellis, 1984), tense and aspect (e.g., Bardovi-Harlig, 1995), and word-order (e.g., Ellis, 1984). Comparing the sets of morphosyntactic features selected to substantiate the claims of each hypothesis, it seems reasonable to assume that different teaching strategies may be necessary for the teaching of different morphosyntactic features. Whether the patterns observed here for morphosyntax applies to different aspects of phonological development remains an empirical question that should be addressed with the investigation of a wider selection of L2 phonological phenomena.

The study inquired about the effects of type of instruction on the development of each sC structure. Based on previous studies involving morphosyntax (e.g., Zobl, 1985; Yabuki-Soh, 2007), it was hypothesized that there would be a correlation between these two linguistic fields, phonology and morphosyntax, with results favouring groups that are taught the most marked form of a given developmental hierarchy. While there are no phonological studies with which these results could be compared (except for a pilot study reported in Cardoso, 2010), the findings presented here are consistent with those observed in previous studies involving the acquisition of morphosyntactic features (e.g., the acquisition of relative clauses; Eckman et al., 1988; Roberts, 2000; Ammar and Lightbown, 2004; Yabuki-Soh, 2007).

Could it be that a piecemeal (rather than an all-at-once) approach to teaching could partially explain the results? Although not originally conceived to address phonological difficulty, one possible theoretical explanation as to why a piecemeal approach could be beneficial for sC acquisition might come from Cognitive Load Theory (Chandler and Sweller, 1991). Briefly, Chandler and Sweller propose a framework for instructional designers and teachers that allows them to control the conditions for learning by reducing extraneous cognitive load. They assume that there is a single and limited cognitive resource to acquire new knowledge, so the addition of more items to the process may limit the amount of resources available for learning. In the current study, the reduction of learnable sC structure in the P Group to one item (the most marked /st/) per teaching session might have triggered a focus toward that single unit, thus rendering the overall learning process more effective. Regardless of the reasons why learners performed better in a piecemeal instructional environment, from a pedagogical standpoint, these results suggest that gradually providing learners with the elements that constitute a given developmental sequencing could be conducive to better L2 speech production. Clearly, this topic is worthy of further investigation, particularly for developmental sequence phenomena.

A tangential but interesting finding uncovered by this research was the "task effect" observed between the *Read Aloud* and *Listen and Repeat* tests, with only the former displaying significant differences in performance (see Cardoso et al., 2009 and Saito and Plonsky, 2019 for similar findings in L2 pronunciation studies). One possible explanation for this test-related disparity may be due to the cognitive characteristics of the two tests: while *Read Aloud* relied heavily on the participants' ability to recall and orally produce the target sC forms (e.g., with the aid of grapheme-to-phoneme associations, which characterize the act of reading aloud), *Listen and Repeat* depended on the participants' ability to imitate speech, considered a less cognitively demanding activity (e.g., Alós-Ferrer and Schlag, 2009). In fact, reading aloud has been recognized as a by-product of the development of accuracy and automaticity in reading, a cognitively demanding task that includes both phonological and orthographic processes to access, process and orally produce written forms (Hudson et al., 2008). Another possible explanation relates to the level of attention paid to speech, a concept that is often operationalized as level of formality or style. As has been attested in the sociolinguistic literature (e.g., Major, 2004), more formal tasks (styles) such as reading aloud have greater propensity for target-like forms in comparison with less formal activities such as imitating one's speech. Despite these task effects, the results obtained in *Listen and Repeat* confirm that a focus on the most marked /st/ is the most effective way of teaching sC clusters, as the group that was taught exclusively this form was still able to project the acquired knowledge to other clusters, even without any exposure to them, in both tests.

Finally, this study indirectly investigated the effects of sonority within the sC cluster based on the markedness relations motivated by the principles of Sonority Sequencing and Minimal Sonority Distance. Findings related to this question, observed at the last stage of sC development covered by this study (delayed posttest), revealed that, *a priori*, the development of sC clusters across the three experimental groups does not fully conform to what is predicted by sonority and its markedness effects and some of the current literature on sC acquisition. Consider, for example, the results for the *Read Aloud* test, an activity that we claim to represent aspects of the participants' phonological knowledge (i.e., in comparison with imitative *Listen & Repeat*) because it involves the processing of grapheme-to-phoneme rules and it does not rely on the participants' ability to mimic speech (see preceding paragraph). In this task, the most marked /st/ was found to be the more easily acquired in two of the experimental groups: Groups P and T, but not M. These findings seem to corroborate Cristófaro-Silva and Freitas (2020) analysis for Mineiro, a regional BP variety; they found that two phonetic representation co-exist for sC, depending on whether the word is native to Portuguese (is.C) or a borrowing (sC) (see also Collischonn and Schwindt, 2005 for an analysis in which the underlying representation for fricative plus consonant sequences do not contain a vowel).

However, we would exert caution when interpreting these results. First, this study was not designed to examine the acquisition of sC onsets (see Cardoso and Liakin, 2009 for a similar study conducted in a naturalistic, ecologically valid setting). Instead, it was designed to investigate the effects of three types of instruction on the development of these clusters, using a highly controlled (and consequently unnatural) methodology. Second, the Groups that displayed higher rates of /st/ production were the ones in which the participants received instruction on /st/ last, possibly indicating an immediate post-treatment effect. Finally, the only group that behaved in a predictable manner was Group M, in which the least marked /sl/ cluster was more prevalent. Interestingly, this is the group that most resembles a natural learning environment in which the three sC forms are taught in tandem. The results pertaining to a developmental sequence between /sl/ and /sn/, as predicted by Clements' (1990) Minimal Sonority Distance (MSD) and some of the previous studies (e.g., Carlisle, 2006), was not borne out, since the difference in performance between the two clusters was not significant across the three instructional groups. This suggests that although the L2 learners who participated in this study are sensitive to sonority sequencing and its markedness effects on syllabifying foreign sC clusters, they remain oblivious to other principles such as the MSD and, consequently, they process these clusters in a bipartite way in which /s/ + sonorants (/sl/ and /sn/) pattern together as a set in opposition to the most marked /st/ cluster. In a study conducted in a natural (i.e., not MLS-based) language learning classroom setting, Cardoso and Liakin (2009) examined the acquisition of English sC by the same speech community of L2 learners investigated in this study and found identical patterns of acquisition. Not being an idiosyncrasy of BP L1 speakers, similar patterns have also been found for other language backgrounds in both L1 (e.g., Yavaş and Barlow, 2006; Hefter and Cardoso, 2010) and L2 acquisition (e.g., Rauber, 2006; Boudaoud, 2008).

To conclude, although sonority-based markedness is a good predictor of the order in which sC clusters are acquired, this study has also shown that instruction can somehow alter patterns of acquisition, as has been shown by the works of Ammar and Lightbown (2004), Eckman et al. (1988), Roberts (2000), and Yabuki-Soh (2007). Contra Felix (1981), this study has also shown that formal instruction followed by explicit feedback can indeed minimize the impact of the processes that "constitute man's natural ability to acquire language" (p. 87).

CONCLUDING REMARKS

This study's goal was to examine the effects of three types of instruction on the development of foreign sC clusters to determine which is more pedagogically effective. The results have shown that instruction plays an important role in the acquisition of sC clusters. Specifically, our findings show that a piecemeal introduction to novel sC forms may lead to better oral performance, particularly if the introduction starts from the more difficult and marked end of the developmental hierarchy. As such, this study constitutes the empirical evidence needed to substantiate Eckman and Iverson (1997) and Doughty and Williams (1999) pedagogical recommendations that problematic L2 sounds be taught first in the most difficult and latest acquired (marked) environment, as discussed at the outset of this paper.

Although this study has revealed some interesting findings about the effects of instruction on the teaching of a phonological developmental sequence (sC), it has uncovered some limitations that need to be acknowledged and addressed in future research. Primarily, among its major shortcomings is the adoption of an artificial language, Taki, to test the hypotheses regarding the teaching of developmental sequences. As indicated earlier, while this allowed us to tightly control several confounding aspects commonly found in the standard language classroom (e.g., the students' previous experience with the target form, the quantity and quality of the L2 input, the quality of the pedagogical intervention), one can certainly question its ecological validity: The teaching environment simulated in this study reflects only a fraction of the richness that characterize the L2 classroom reality. Accordingly, we must exercise caution in generalizing our findings because, despite being high on reliability (Hulstijn, 1997), studies with low ecological validity cannot be generalized beyond the settings where they were carried out. Despite this limitation inherent to the laboratory approach adopted, we hope that future research will address similar questions in a more ecologically valid environment, with a natural target language and in authentic language learning settings.

Another important limitation is that the participants in the Teachability Group were not tested at different stages of the experiment to confirm if they had indeed acquired the sC cluster targeted in each instructional session. As discussed earlier, the premise of the hypothesis represented by this group presupposes that a novel linguistic form can only be acquired when learners are ready for the next developmental stage (Pienemann, 1998; Pienemann et al., 2005). Without clear evidence that learning took place at each instructional stage, it is difficult to confirm whether the learners were in fact developmentally ready to learn a more advanced structure, particularly for sC items that were introduced early in the experiment (i.e., /sl/ and /sn/). However, based on the immediate posttest results obtained for the last item introduced to this group (i.e., /st/), we are confident that some learning took place during the teaching sessions. For instance, in both *Read Aloud* and *Listen and Repeat* tests, the participants significantly improved in /st/ production from pretest to immediate posttest from 0.66 to 2.24 (*Read Aloud*) and 1.63 to 3.08 (*Listen and Repeat*), respectively. The issue remains a critical limitation of this study, which we plan to address in future research.

Certain aspects of the research design also limit the implications and generalizability of the results reported. First, due to time constraints and the participants' fatigue after having already participated in three tests (in addition to surveys and interviews), only the effects of the "short-delayed" posttest were investigated, which did not allow us to observe long-term effects of the different types of pedagogical interventions adopted in the study. While the adoption of a "short-delayed" posttest was included as a compromise to slightly delay the posttest and at the same time reduce the number of tests, the literature provides strong evidence that L2 instruction decrease gradually between immediate and delayed posttest (Norris and Ortega, 2000; but see Mackey and Goo, 2007 and Lyster and Saito, 2010 for contradictory findings). Secondly, the pedagogical interventions adopted relied exclusively on the teaching of a small set of phonological features (sC) in a vocabulary acquisition context. A natural question that arises from such a limited pronunciation focus is whether learners would have performed differently had they been provided with opportunities to transfer the newly acquired knowledge to high-level communicative tasks as spontaneous speech (see Couper, 2006 and Derwing and Rosita, 2003 for evidence of how phonological gains obtained *via* instruction can be transferable to other lexical environments or spontaneous speech).

Despite these limitations, some pedagogical implications can be derived from our findings. Assuming that they can be extrapolated to "real-life" teaching, the most obvious recommendation would be for L2 teachers of sC languages such as English, French, and German to start instruction from the hard-to-acquire end of the developmental hierarchy, /st/ (possibly including other /s/ plus stop clusters such as /sp/ and /sk/). Due to the frequency distribution of sC forms in these languages, this is a relatively easy move, considering that /st/ comprises the vast majority of sC forms in most languages. In English, for instance, /st/ constitutes 87.4% of all sC forms in student-directed teacher speech and 87.9% in the Brown Corpus (Cardoso and Liakin, 2009). Following Celce-Murcia et al. (2010) framework for teaching pronunciation, instructors could initially engage students in sound awareness and listening discrimination activities so that learners can hear and discriminate the differences between the L1-influenced form (e.g., *[i]stop, *s[u] top) and the target /st/ (e.g., /st/op). This could be followed by controlled practice in which there is a focus on sC articulation accompanied by teacher-or peer-based explicit feedback (e.g., using tongue twisters such as "Stella, stop selling stocks," or the exaggerated/lengthened pronunciation of /s/ so that it sounds like a separate syllable, taking advantage of this segment's continuant characteristic: /s:.t/op-see Cardoso and Liakin, 2009 for the rationale behind this recommendation). Finally, students could practice the newly-acquired forms in spontaneous, less controlled activities such as preparing and orally presenting a set of suggestions on how to succeed as a language student (e.g., /st/udy every day, /st/ay cool when you make mistakes). Based on the findings reported here, following these recommendations, the effects of an instructional focus on the hard-to-acquire /st/ will likely project to the forms that are assumed to be more easily acquired, /sn/ and /sl/.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Concordia University's Ethics Committee (Office of Research). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2021.662934/full#supplementary-material

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