Click consonant phonotactic learning: An investigation of phonotactic learning with click consonants in English speakers

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Abstract

Many African languages use clicks as consonants and in this study, we investigated phonotactic learning by native English speakers of first-order constraints with two types of clicks, dental and alveolar. Specifically, we are interested in whether people can implicitly learn phonotactic constraints involving sounds that do not occur in their native language. Learning was measured through the types of speech errors produced. If these errors tend to obey the experiment's rule, learning has taken place. However, if they don't, learning has not taken place. The experiment involved participants reciting consonant-vowel-consonant syllables on two different days and the rules involved whether a click can occur in the beginning or end of a syllable. The first day was a practice/ training session and the second day was the actual experiment. The results show that English speakers did learn the click positions when compared to the regular-consonants through restricted and unrestricted legality errors. But clicks do not stick to their positions as much as the regular consonants do. This implies that English speakers do not treat clicks like other consonants.

What are clicks?

African languages such as Zulu with words such as “khwe” not only use a phonotactic rule set that wildly differs from English, but also incorporates a new dimension of phonotactic rules: clicks and whistles. In fact, such clicks are whistles are present in many African languages, where such components occur as consonants. It should be noted that this is not, however, limited to African languages. English uses clicks, but in a rather difference sense. For example, the most common click sound in English is the when one uses it express disproval: “tsk tsk tsk”. This is significantly different in the African languages. Taking Zulu for example, it is known that a specific series of clicks can be used to encode "yes" or "no" in various formats, even showing tone within clicks. By adding clicks to a language, the size of the language increases dramatically.

One can compare English’s “24 consonants and 14 vowels” to Zulu’s “59 consonant sounds, and seven vowels” (Naidoo, 2005). Such a vast increase in the number of consonants present in the Zulu language seems to point to the difficulty in learning the language, or just the phonotactic rules of the language. However, this study chooses to focus only on the consonant-clicks present here. Notably, one-seventh of all Zulu words have a click, with the clicks being present in three positions: dental, lateral, and alveolar.

The dental click is the easiest to produce for non-native click speakers. As presented in the English language click example above, the “tsk” sound is a dental click. This is produced through a movement of the tongue that sucks in air behind the teeth, resulting in a sound. The second type of click that can be produced is the alveolar click. There is no English language equivalent for these clicks, which are produced by moving the tongue from the roof of the mouth to the base, sometimes by moving the jaw. This produces a loud click, almost sounding like a pop.

Although these click sounds themselves are fairly standard between languages, the phonotactic constraints they represent can be wildly different (Miller, 2011). Such differences are rooted in the histories of the various languages and their divergence in Africa. It is thought that clicks originated from groups of Bantu languages. Bantu languages are a large group of languages spoken by the Bantu people in the Sub-Saharan Africa. They are part of the Southern Bantoid group which related to the Benue-Congo language. There is an estimated of 400-500 Bantu languages and 400-600 distinct languages

Background

Speech errors or slips are used to study learning in speech production. Speakers don't intend to make slips and so speech errors show our unconscious understanding of the structure of speech production and implicit learning in production (Warker & Dell, 2006). Phonological acquisition begins at the first year of life (Jusczyk, Cutler & Redanz, 1993). Infants young as 10.5-16.5-month-old can learn novel phonotactic constraints (Chambers, Onishi & Fisher, 2011). According to Dell, Reed, Adams, & Meyer (2000), participants immediately learn restricted consonant positions called first order constraints. A first order constraint is a rule on the position of the consonants that does not depend on any aspect of the syllable whereas second order constraint is where a consonant position is dependent on adjacent vowel. For instance, */f/* is an onset in all of the syllables of the experiment would be a first order constraint, but /f/ is an onset if the vowel is */ae/* would be a second order constraint.

Subjects found it harder to learn second-order constraints and did not learn until the second day of the experiment (Warker & Dell, 2006). Similarly, a study by Onishi, Chambers &

Fisher (2002) demonstrated that, in perception, people can immediately learn first-order regularities in which consonants were restricted. This is where subjects listened to CVC syllables with restricted consonants and had to repeat it as quickly as possible. People also learned second-order regularities (Onishi et al., 2002) in which consonants depended on the adjacent vowel but at a slower reaction time. The results are consistent with Warker and Dell (2006) in that second-order constraints are difficult to learn. Both speech perception and speech production have similar results for second-order constraints. However, people never learned the second-order regularities in which the position of consonants depended on the speaker's voice (Onishi et al., 2002).

In reality, people don't learn language from distinct voices which could explain no learning effect in second-order regularities in which position of consonants depended on speaker's voice. Likewise, Warker, Dell, Whalen & Gereg (2010) showed that speakers can't learn consonant position dependent on the speech rate. Results from Onishi et al. (2002) show implicitly acquiring phonotactic constraints from experience depends on features within the phonological system (Warker et al., 2010). However, this experiment doesn't involve second-order constraints because producing clicks on its own is difficult enough.

Native English speakers cannot learn tone-based phonotactics after two days of training in second-order constraints, for example, /f/ is an onset if the syllable is a rising tone but coda if it's a falling tone (Bian & Dell, 2018). This is possibly because English is not a tone-based but stress-based. Speakers (Bian & Dell, 2018) learned stress-based phonotactics after two days of training.

English words have strong stress on initial syllables. A study by Jusczyk et al. (1993) examined if sensitivity to predominant stress patterns of words could play a role in lexical

development. It showed that 9 month-old American infants listen longer to initial strong stress followed by a weak stress patterns than words with initial weak stress followed by a strong stress (Jusczyk et al., 1993). However, 6 month-old infants did not show preference to predominant stress pattern, suggesting sensitivity to predominant stress patterns of words develop due to increasing familiarity prosodic aspect of one's native language (Jusczyk et al., 1993). In the present study, we might expect no learning of first order rules involving click consonants in native English speakers since English speakers do not use clicks when they produce syllables.

Method

12 native English speakers from the University of Illinois of Urbana-Champaign were paid $20 to participate in a two part study on two different days. On the first day, participants practiced producing clicks sounds with the metronome and no data was recorded. On the second day, participants who were able to produce click sounds participated in the experiment and data was recorded. Each subject had two restricted consonants, either both regular consonants, a click and regular consonant or both click consonants. Each participant was randomly assigned a restricted consonant condition. Regular consonants were combined with clicks to produce syllables. The regular consonants used were *f, k, p, ch, s* and *t* and the two click consonants were | (dental) and ! (alveolar). In the original study, Dell et al., 2000, participants recited 4 syllables containing eight different regular consonants and a single vowel. For example, "hes, meng, fek, neg" Similarly in this study, participants had to recite four sequences of consonant-vowel-consonant (CVC) syllables, containing two click consonants and six regular consonants, such as *"|ak !af chas tap."* The first sequence of CVC was practice and the last 3 CVC's was evaluated.

Each subject recited a trial of four sequences 96 times and every trial consisted of two click consonants and six regular consonants. These were the type of constraints for each participant:

1. *Experiment-wide constraint*: consonants were restricted. For example, /t/ is an onset and /!/ is a coda throughout the experiment.
2. *Unrestricted consonants*: unlike experiment-wide constraints, the unrestricted consonants could appear both as onsets or codas.

Warker & Dell (2006) also experimented with language-wide constraint. For example, /ŋ/ cannot be an onset in any English word and /h/ cannot be a coda in any English word. In language-wide constraint, speech errors obeyed 100% of the time. Specifically, when participants made speech errors. /ŋ/ would always move to a coda position and /h/ would always move to an onset position. However, for this experiment, language-wide constraint with clicks was not explored simply because the subjects were native English speakers. This implies that experimenting against language-wise constraints respective to clicks would not be worth the effort.

Materials and Procedures

In this experiment, we used two click consonants; dental and alveolar (written as | and ! respectively). The dental click is produced by placing the tip of the tongue against the roof of the mouth touching the upper teeth and bringing the tongue down. The alveolar click is produced by placing the tip of the tongue against the roof of the mouth behind the alveolar ridge and bringing the tongue down. We chose these two clicks because they were the easiest for English speakers to produce. The dental click is like the sound *"tsk tsk tsk",* and the alveolar click is the sound that people used to use to get horses to start walking. Each participant recited 96 sequences

composed of four CVC syllables. A computer program randomly generated the list. There was a total of 12 restricted conditions; *tk, kt, |t, t|, ! t, t!, k|, |k, k!, !k, |!*, and *!|*.

Participants practiced producing click sounds several times in their own comfortable speed before reciting the sequences at a faster speed in time with the metronome. If participants felt comfortable produce clicks in complex syllable, such as "|*am*", they would practice producing sequences that were presented one at a time on a computer screen in time with the metronome. First, participants would recite the first sequence at a slow rate of one syllable per second. Then they would repeat the sequence three times at a faster rate of 2.53 syllables per second without pausing. Participants spoke directly into a head-mounted microphone.

Results

There were 248 errors involving experiment-restricted regular consonants (that is, not clicks). The restriction definition is similar to that used in other studies of this kind, where certain consonants or clicks are restricted to particular syllable positions and the other consonants or clicks are unrestricted. There were two classes of these experiment-restricted consonant errors. The first was a legal slip - if the slip adhered to the rule in the current condition, and the second was an illegal slip – if the slip did not adhere to the rule in the current condition. This can be explained by looking at the simple phrase *"tas fach"*, spoken by a participant in a condition in which /t/ was restricted to the onset position. It can be seen in this example that the first word has an onset of /*t*/ and a coda of /s/, and in the second word we have an onset of /*f*/ and a coda of /*ch*/.

Suppose we have an error of "*tas **t**ach*"; here we can see that the /*t*/ has slipped to an onset position of the second syllable. This is a legal error, as we have moved an onset to another onset position -- so, the /t/ followed the rule that /t/ must be an onset. However, if we made an error such as *"tas fa**t**"*, this would be an illegal error, as we have moved an onset to a coda position (onset /*t*/ has replaced coda /*ch*/). Of the 248 experiment-restricted consonant slips, 220 were restricted legal consonant errors and the remaining 28 were illegal, leading to proportions of 88.7% restricted legal consonant errors and 11.3% restricted illegal consonant errors.

In addition to this, we have a set of experiment-unrestricted consonant slips, where1559 errors were found. These are slips of regular consonants (not clicks) that could occur as both onsets and codas for that participant. The same legality rules that were previously defined for restricted slips can be applied here as well. There were 1122 unrestricted legal consonant errors and 437 unrestricted illegal consonant errors. This gives us a proportion of 72.0% unrestricted legal consonant errors and 28.0% unrestricted illegal consonant errors. The fact that restricted consonants slips were 88.7% legal and unrestricted consonant slips were only 72% legal suggests that the participants had learned the rules on the restrictions.

Such results are consistent with those found in the (Dell et al., 2000) study, where restricted legality of consonants was significantly higher than unrestricted legality. In order to verify that this was true in the current experiment, the portion of restricted consonant slips that were legal was compared to the proportion of unrestricted consonant slips that were legal. In addition, as done in previous studies of this class, the nonparametric Wilcoxon signed-rank test was used to test the difference.

When comparing restricted legal consonant errors to unrestricted legal consonant slips, we found that there was a significant (Wilcoxon p= 0.04883) difference between the restricted and unrestricted legal consonant errors, supporting the hypothesis formed in previous studies and validating experimental design. It should be noted that when computing this Wilcoxon test, values that did not make sense were removed. For example, participants that did not have any restricted consonant slips, were not factored into the Wilcoxon test, which avoided the use of undefined values in the tests. In addition to this, it is important to know how the Wilcoxon test was computed. While the standard paired, two-sided, Wilcoxon test was used, instead of using raw error counts, the percentage values were used, as this would allow for us to normalize click and regular-consonant counts.

With all of this established, analysis can turn to the focus of this study, the phototactic learning of clicks in native English speakers. As we mentioned, clicks come in two forms in this study, the dental click and the alveolar click, represented by "|" and "!" respectively. These clicks were restricted and unrestricted in the same way as the consonants. In addition to this, legality of slips was expressed in the same way as prior. That is to say if there was a phrase *"|af pach"* then "|*af ac`h"* would be considered a legal error and *"|af pa|"* would be considered an illegal error, by the same method as previously described.

When looking at restricted click errors, there were a total of 185 errors made. Of these errors, they were binned into the legal and illegal groups with values of 68 and 117 respectively. This gives us proportions of 36.7% for restricted legal click errors and 63.3% for restricted illegal click errors. Unrestricted click errors were also observed, with a total of 222 errors were made. Of these, 62 errors were legal while 160 were illegal. This then gives us proportions of 27.9% unrestricted legal click errors and 72.1% unrestricted legal click errors.

Simply looking at these proportions, we can see they wildly vary from those found with regular-consonants, both restricted and unrestricted. Looking at restricted consonant legal errors, we have a proportion of 88.7%, however, comparing that to restricted click slips that are legal, we see a significant drop to 36.7%. The same occurs when looking at unrestricted consonant slips. In the consonant case, we have 72.0% legal unrestricted slips, while in the click case we have 27.9% unrestricted legal slips. This large drop in legality would point to the fact that the clicks did not stick to their syllable positions the way that regular consonants did. This suggests that the when English speakers make a click, they are not really thinking of it as part of a syllable.

Wilcoxon tests were also performed to test whether there is any learning of the restrictions on the click positions. Specifically, we test the significance of the contrast between restricted click errors that were legal and unrestricted click errors that were legal. For the first case – restricted clicks against unrestricted clicks, both legal – we saw a Wilcoxon p value of 0.01563, indicating that the difference between restricted and unrestricted legal click errors was statistically significant. Such results are encouraging, as they demonstrate, with further analysis, that participants may have learned phonotactic click constraints

The final piece of analysis here comes when we compare the differences between the regular consonants and click results. First, we can look at Figure 1 and see that in both the cases of the regular consonants and clicks, the restricted group always had a higher percentage than the unrestricted group. As previously stated, noticeably different are the proportions of these percentages, but the important part is that in both regular-consonants and clicks, we observe the same type of learning.

In order to try and justify this data, we can try and look at how slips were made. In specific we can look at data showing what the original regular-consonant or click was, and what the slip was, indicating what subjects would tend to err towards. Looking at Figure 2, we can see that by a large margin, errors tended to be consonants that slipped to consonants, with a value of 1699 errors. 301 errors of the consonant to click class were made, 248 of click to consonant and 159 of click to click. Proportionally this led to percentages of 70.5%, 12.5%, 10.3%, and 6.6% respectively.

With this data, we can perform a phi test to see if there is a relationship between slips. Performing such an analysis on the data, as presented in table 3, a phi value of 0.22896 was obtained. This would indicate that there is some correlation between how these slips occur, however, this result is possibly skewed due to the large amount of consonant to consonant slips, which would exist simply due to the number of consonants present in the study, when compared to the number of clicks present.

Discussion

The initial results from this study were as expected. The regular-consonant portion of this experiment verified the work of others, such as Dell et. al. (2000), and showed that English speakers can learn regular-consonant phonotactic constraints. This was, of course, shown through the fact that restricted-consonant legality was observed to be greater than unrestricted-consonant legality at a statistically significant level.

This study expanded on this idea of regular-consonant phonotactic constraints by introducing clicks as constraints and seeing if English speakers could learn such phonotactic

constraints. As the results show, there is some evidence that shows that phonotactic constraints were learned. We can see that both regular-consonants and clicks have higher proportions of legal restricted clicks compared to legal unrestricted clicks, respective to regular-consonants and clicks, this can be seen in Figure 1. Such a result indicates that in general, participants could learn the phonotactic constrains present in clicks. This indicated that in general participants could learn legal restricted slips better than legal unrestricted slips, a continuation of previous work done in the field. Indeed, this shows that participants did clearly show a significant distinction between restricted and unrestricted movements even in clicks.

Participants were able to produce the two types of clicks present in the study, but with a high rate of error when it came to obeying the rules of the clicks. As the study shows, participants were making legal click slips, but were primarily making illegal click slips, of both the restricted and unrestricted type. This thoroughly indicates a failure to learn that the participants slips did not obey the rules set up by the study. Rules such as /|/ being placed as the onset but using the /|/ to slip the coda. Nevertheless, the fact that more restricted errors exist compared to the unrestricted errors, specifically for legal clicks, indicates that some learning did occur. Thus, our findings show that in terms of linguistic experience in English speakers, phonotactic constraints related to clicks are learnable to an extent. When compared with previous studies in the field, our results are in line with what has been established, albeit to a lesser degree.

Firstly, it must be noted that this study is not conclusive on this subject. Firstly, this study only covers the very basic types of clicks. Other types of clicks could lead to better subject performance due to ease of pronunciation, which could indicate why click restrictions were

difficult to learn. This study can simply conclude that the hypotheses presented here were supported and can be summarily defended.

This study also noted what slips were moving towards. Overwhelmingly, it was shown that consonants tend to slip towards consonants. Moreover, it can be seen that clicks tended to slip towards consonants as well. These findings are detailed in Figure 2. What these results allude to is that participants are not treating clicks as syllables or parts of syllables, but rather as individual phrases. This is most likely due to the fact that English speakers do not have experience with clicks in syllables, and longer exposure to a language or phonotactic constraints may lead them to learn this.

Nevertheless, such a study presents many avenues for future development, in many fields. Firstly, we can expand this study this study by having more carefully selected phrases for subjects to learn. This comes off of what could be described as a flaw in this study where carefully selected phrases could give more evenly distributed data and give more conclusive results. A secondary study designed around more carefully picked phrases could try and test for more subtle learning of phonotactic constraints in clicks. In addition to this, a longer time scale for learning the constraints could be employed, such as two to three weeks, especially for native English speakers. This longer time scale might allow for these native speakers to glean how clicks can be part of syllables can use them more effectively.

In conclusion, this study the experiment in this study examined the limits of native English speakers when it comes to learning the phonotactic constraints of clicks in a language. Our results showed that clicked based phonotactic constraints can be learned, albeit to a lesser extent than regular-consonant phonotactic constraints. In addition to this, it was shown that when participants made slips, they tended to slip consonants to consonant positions, and clicks to

consonants as well. This implies that participants did not learn how to use clicks as parts of syllables, but rather as their own unique components.

Appendix

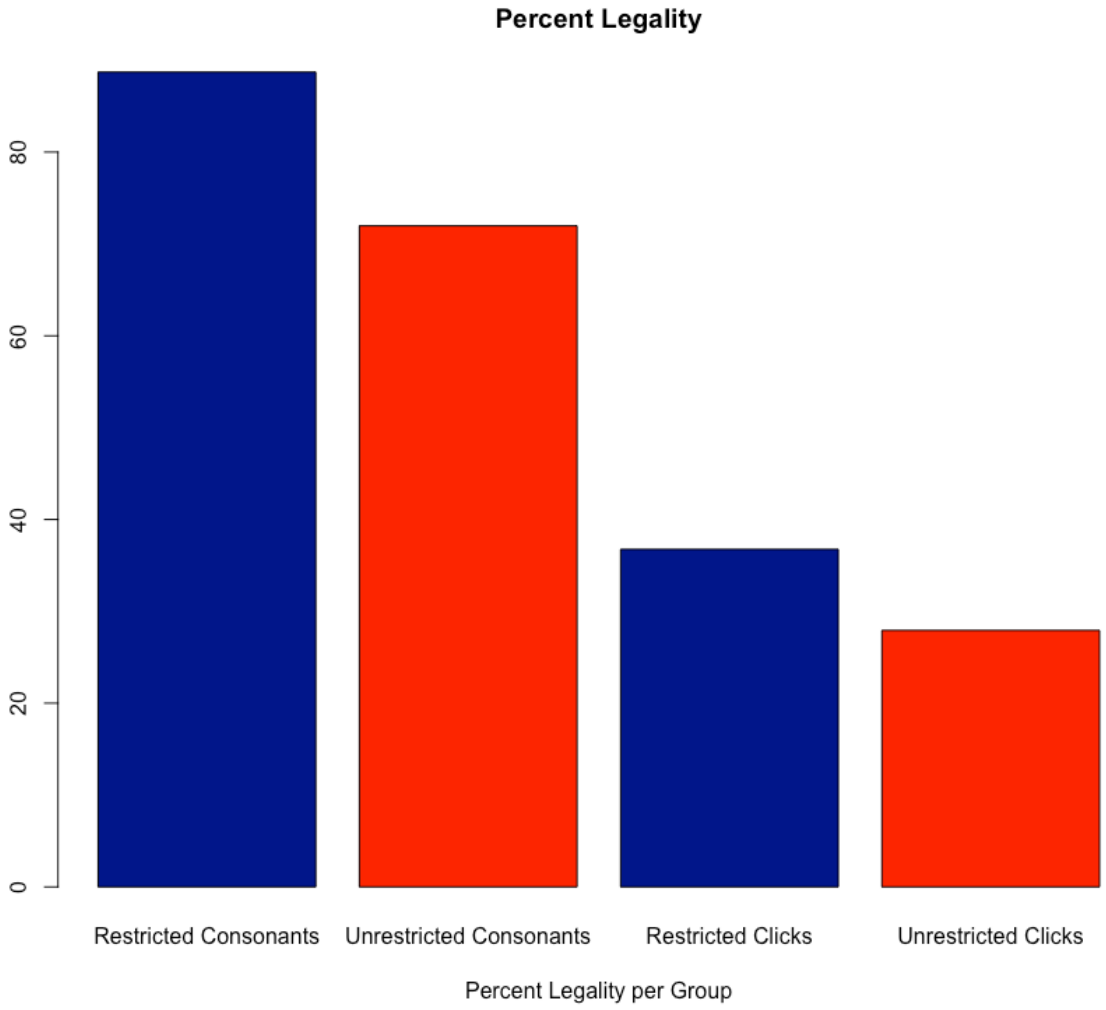

Figure 1: Percentage of legality for consonant errors and click errors

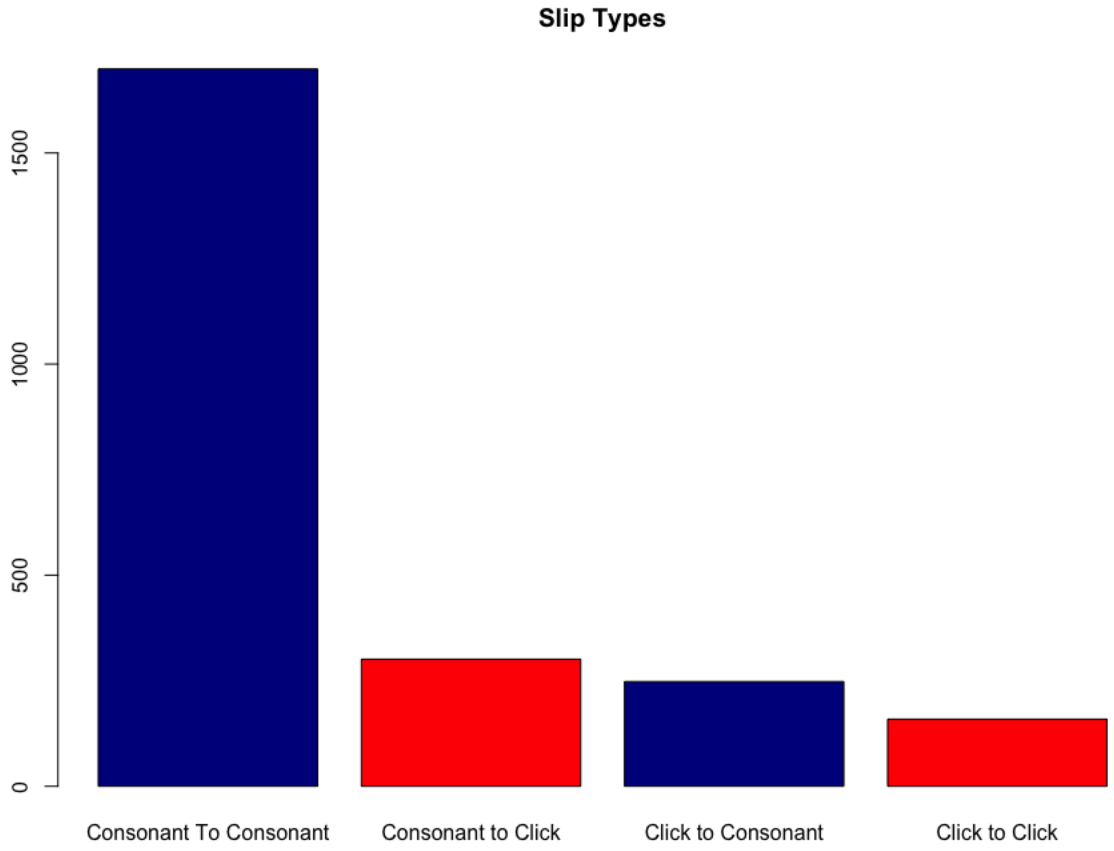

Figure 2: The type of slip made, from source to error

Table 1: Total number of consonant slips

	Restricted	Unrestricted	Total
Legal	220	1122	1342
Illegal	28	437	465
Total	248	1559	1807

Table 2: Percentage of total legality

	Consonants	Clicks
Restricted	88.71%	36.76%
Unrestricted	71.97%	27.93%

Table 3: Comparing Types of Slip Positions

	Consonant Slip	Click Slip
Consonant Slip	1699	301
Click Slip	248	159

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