1. Introduction
   a. Big Questions:
      i. Why is there a naturalness bias in L1\(^1\) learning?
      ii. Are there different biases in L1 and L2 learning?
      iii. Why do some artificial language studies find an effect of complexity, but
           L1 studies don’t?
   b. A “surfeit of the stimulus” (Becker et al 2011) exists in language learning
      i. There are more patterns in a language’s phonotactics than are learned by
         speakers (Hayes and Wilson 2008).
      ii. There is likely a systematic bias that determines which of these are learned
         (Hayes and White 2013).
   c. Naturalness
      i. A pattern is considered (in this study) natural if it is phonetically grounded
         (Hayes 1999) and typologically common.
      ii. Studies have shown that speakers have a bias for learning the natural
         patterns in their L1 (Hayes and White 2013; Prickett 2014)
   d. Complexity
      i. A pattern is considered simple (in this study\(^2\)) if it involves a low number
         of variables (Bulgarella and Archer 1962).
      ii. Participants in artificial language studies tend to have a bias for learning
         simple phonotactic patterns (for example, Skoruppa and Peperkamp 2011;
         see Moreton and Pater 2011: Parts I and II for a review of many similar
         studies).
   e. Artificial language studies vs. First language studies
      i. Artificial language studies (such as Skoruppa and Peperkamp 2011) find a
         complexity bias, but no naturalness bias.
      ii. First language studies (such as Prickett 2014) find a naturalness bias, but
         no complexity bias.
      iii. One reason for this could be that a naturalness bias exists only in L1
         learning.
      iv. If this is the case, then L2 learning should behave similarly to artificial
         language learning.

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\(^1\) L1 will be used as an abbreviation of “first language” and L2 will be used as an abbreviation of “second language”.

\(^2\) This is only one definition of complexity that has been shown to affect non-linguistic learning (Bulgarella and
    Archer 1962). For a discussion of the different definitions of complexity used in phonotactic learning studies, see
    Prickett (2014).
2. Design
   a. This study uses a methodology similar to Hayes and White (2013) and Prickett (2014) to test for complexity and naturalness learning biases in L1 and L2 learning.
   b. Predictions
      i. L1 learning is predicted to have a bias for natural patterns (as in Hayes and White 2013 and Prickett 2014).
      ii. L2 learning is expected to have a bias for simple patterns (like the artificial language learning in studies like Skoruppa and Peperkamp 2011).
   c. Languages to test
      i. Two languages were chosen for the purposes of this study: French and English.
      ii. These were chosen for two reasons:
         - English was used in Hayes and White (2013) and an artificial version of French was used in Skoruppa and Peperkamp (2011).
         - There are many L1-English L2-French and L1-French L2-English speakers living in Canada.
   d. Patterns to test
      i. In this study, as in Hayes and White (2013) and Prickett (2014), patterns are in the form of phonotactic constraints.
         - For example, voicing assimilation would be represented as *[+voice][−voice].
      ii. In order to avoid issues of interference (Kilpatrick 2009), only English constraints violated by French words and French constraints violated by English words were used. This created a large limitation on which constraints were eligible and led to the need for more than one source of constraints.
      iii. Constraints sources3:
         - The UCLA Phonotactic Learner (Hayes and Wilson 2008)
         - Hammond’s (1999) phonological grammar of English
         - Walker’s (1984) grammar of Canadian French
         - A manual search for patterns in the CMU pronouncing dictionary4
         - A pattern mentioned by Albright (2008) and confirmed with a search in CMU
      ii. Constraints were found that fell into four categories for each language: Natural Simple, Natural Complex, Unnatural Simple, and Unnatural Complex.

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3 Any patterns that were not in the form of constraints were converted to constraints according to the system used by the UCLA Phonotactic Learner (Hayes and Wilson 2008).
4 http://www.speech.cs.cmu.edu/cgi-bin/cmudict
3. Methods
   a. Stimuli
      i. Two kinds of stimuli were made:
         - Experimental: these stimuli were novel words that violated one of the constraints discussed in (2.d). They did not violate any other constraints found in their language by the UCLA phonotactic learner.
           Example: [ʒa] violates *[+voice, -anterior, +continuant]
         - Control: these stimuli did not violate any constraints found in their language by the UCLA phonotactic learner. They also had an experimental partner which they only differed from (if possible) by a single phonetic feature.
           Example: [dʒa] and [ʒa] differ only in the feature [continuant]
      ii. Stimuli were presented to the participants in the form of orthography and audio recordings.
         - Recordings were made by a speaker of both French and English.
         - Orthography was made from suggestions given by a speaker of both French and English, with some slight alterations.
   b. Materials
      i. The experiment was run online in two sections: a section testing stimuli made for English constraints and a section made for testing French constraints.
      ii. The order of the two sections was counterbalanced across participants and the order of the stimuli was randomized within the sections.
      iii. Demographic information was also collected.
   c. Participants
      i. 30 eligible subjects participated in the experiment.
         - 10 L1-French L2-English speakers
         - 20 L1-English L2-French speakers
      ii. Subjects were recruited through Mechanical Turk, social media, and email.
   d. Procedure
      i. Participants first verified their knowledge of French.
      ii. They were then directed to an instructional page.
      iii. After this, they were presented with the stimuli and asked to rate each one numerically on how “good” it sounded for that section’s language.
      iv. This method, known as magnitude estimation has been shown to be an accurate measure of grammaticality (Bard et al.1996).
4. Results
   a. L1 Effect
      i. The L1 Effect was measured for each of the constraint categories (Natural Simple, Natural Complex, Unnatural Simple, and Unnatural Complex).
      ii. This was defined as:

\[
(\text{experimental} - \text{control})_{\text{English}} - (\text{experimental} - \text{control})_{\text{French}}
\]

   Where “experimental” and “control” represent the mean natural log of the ratings for the experimental and control stimuli in each category, respectively.

   iii. This represented the difference in each category’s effect on L1 and L2 learning, since the effect of a constraint would be the difference between the rating of a word that violated only that constraint (the experimental stimuli) and a word that didn’t violate any (the control stimuli).

   b. A comparison of L1 Effects
      i. L1-French L2-English

<table>
<thead>
<tr>
<th>L1 Effect Comparison</th>
<th>Estimate</th>
<th>Lower CL</th>
<th>Upper CL</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS (L2 - L1) - US (L2 - L1)</td>
<td>-0.1353</td>
<td>-0.5149</td>
<td>0.2442</td>
<td></td>
</tr>
<tr>
<td>NS (L2 - L1) – NC (L2 – L1)</td>
<td>-0.0682</td>
<td>-0.4301</td>
<td>0.2937</td>
<td></td>
</tr>
<tr>
<td>US (L2 – L1) – UC (L2 – L1)</td>
<td>-0.3932</td>
<td>-0.7565</td>
<td>-0.0299</td>
<td>+</td>
</tr>
<tr>
<td>NC (L2 – L1) – UC (L2 – L1)</td>
<td>-0.4603</td>
<td>-0.9206</td>
<td>-0.0001</td>
<td>-</td>
</tr>
</tbody>
</table>

      ii. L1-English L2-French

<table>
<thead>
<tr>
<th>L1 Effect Comparison</th>
<th>Estimate</th>
<th>Lower CL</th>
<th>Upper CL</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS (L1 – L2) - US (L1 – L2)</td>
<td>0.0587</td>
<td>-0.2889</td>
<td>0.4063</td>
<td></td>
</tr>
<tr>
<td>NS (L1 – L2) – NC (L1 – L2)</td>
<td>-0.0282</td>
<td>-0.4395</td>
<td>0.3830</td>
<td></td>
</tr>
<tr>
<td>US (L1 – L2) – UC (L1 – L2)</td>
<td>-1.2837</td>
<td>-1.6712</td>
<td>-0.8961</td>
<td>-</td>
</tr>
<tr>
<td>NC (L1 – L2) – UC (L1 – L2)</td>
<td>-1.1967</td>
<td>-1.5122</td>
<td>-0.8812</td>
<td>+</td>
</tr>
</tbody>
</table>
c. **Interpretation**
   
i. The column labeled “Prediction” in the tables above represents the value that the number would have (either negative or positive) if L1 learning had a significantly larger naturalness bias and if L2 had a significantly larger complexity bias.

ii. Neither group of speakers’ ratings seem to go in the predicted direction for both naturalness and complexity. Instead, English constraints seem to have the stronger effects (regardless of speakers’ L1).

iii. This means the two groups’ results go in opposite directions of one another.

5. **Discussion**

   a. Could the data from one of the speaker groups (L1-French L2-English) be flawed?
      
i. Both groups seemed to have learned the French patterns worse.
      
ii. Since the experiment was made for Canadian French, other dialects of French could have caused issues with subjects’ grammaticality judgments.
      
iii. L1-French speakers are a minority in Canada, which might have also influenced their judgments5. The large amount of English loans in Canadian French has been long noted (Leechman 1950) which could support this idea.

   b. **Future Work**
      
i. Does interference need to be a concern?
      
ii. Could there be a better pair of languages to choose?
      
iii. Does magnitude estimation allow too much variance for an experiment of this kind?

   c. **Conclusions**
      
i. If the L1-French L2-English data is ignored, it seems that both complexity and naturalness biases are stronger in speakers’ L1.
      
ii. This does not contradict the idea that naturalness plays an important role in the development of the L1 phonology (Hayes 1999).
      
iii. But it does not shed light on why artificial language studies (like Skoruppa and Peperkamp 2011) come to a different conclusion about learning biases than natural language studies (such as Prickett 2014).
         - This difference could be a result of sleep, as suggested by Peperkamp and Martin (2015).

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References


Hayes, Bruce, and James White (2013). Phonological Naturalness and Phonotactic Learning. Linguistic Inquiry 44.1: 45-75.


