The edge of order: analytic biases in ludlings

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1. The Typological Profile of Ludlings

Language games, or *ludlings*, as they have been called by Laycock (1972), exist in virtually every culture, usually among adolescents, either for the social function of group membership ("secret handshakes") or in order to encode/hide information from one's parents/rivals. While ludlings fall into many types, including iterative infixation (e.g. English *ubbi-dubbi*, Spanish *Jerigonza*, Portuguese *Língua do Pê*), perhaps the best known type are precedence-modifying ludlings that operate at the level of syllables, of which French *Verlan* (from à *l'envers*) is most famous. Syllable-precedence-modifying ludlings exchange the order of syllables in a word and are most commonly employed in disyllabic words (e.g. French *barjot* → *jobard* 'crazy').

Bruce Bagemihl, one of the most ardent proponents of ludlings as an object of linguistic study and as a source of information about possible and impossible operations in the phonological component, conducted an extensive typology of attested and non-attested ludlings (Bagemihl 1989). Some of Bagemihl's generalizations are listed below.

(1)

a. No ludling reverses the middle two syllables
b. No ludling moves the final syllable to the middle
c. No ludling permutes every other segment in a word
d. No ludling permutes feet
e. No ludling permutes subsegmental features
f. No ludling creates palindromes

Following Bagemihl's insight that "Ludlings extend, modify, or exaggerate attested natural language processes", we concur that precedence-modifying ludlings constitute a rich source of information about spontaneous transformations on phonological representations, free of prescriptive influence. Perhaps one of the more interesting findings about ludlings in the world at large is the fact that, while disyllabic reversals of the Verlan type are extremely common, one encounters a great deal of variation with words of longer syllable-counts. An immediate question that arises is the

source of this variation: is anything possible? We submit that this variation emerges as the consequence of ambiguity as to the way of representing the basic transformation in disyllabic forms:

(2) Ambiguity of disyllabic inversion leads to variation on longer forms:

a. Fula: *pii.roo.wal* → *roo.wal.pii*	(Move $\sigma_{1\ (first)}$ to end)
b. Tagalog: *ka.ma.tis* → *tis.ka.ma*	(Move $\sigma_{F\ (final)}$ to start)
c. Marquesan: *nu.ku.hi.va* → *ku.nu.hi.va*	Transpose(σ_1, σ_2)
d. Luchazi: *ya.mu.nu.kwe* → *ya.mu.kwe.nu*	Transpose(σ_F, σ_{F-1})
e. Saramaccan: *va.li.si* → *si.li.va*	Invert order of all σ

What is highly interesting about the five patterns in (2) is the fact that *all of them* are compatible with the disyllabic pattern $\sigma_1\ \sigma_2 \rightarrow \sigma_2\ \sigma_1$. That is, $\sigma_1\ \sigma_2 \rightarrow \sigma_2\ \sigma_1$ can indeed be analyzed as (a) movement of σ_1 to the end, (b) movement of σ_F to the beginning, (c) transposition of σ_1 and its immediate successor, (d) transposition of σ_F and the immediately preceding syllable, or (e) total inversion of the order. It is indeed plausible to think that all five patterns in (2) represent *different ways of generalizing* from the *same ambiguous input*. These ways of extending the disyllabic pattern to tri- and tetra-syllabic patterns have the potential to inform us about how learners generalize based on limited input. However, in the case of ludlings, we do not always know the full corpus of input data, nor whether learners are "explicitly trained" on how to play, and whether they receive negative evidence or corrections.

One of the best ways to investigate "poverty of the stimulus" type questions – that is, the question of how learners generalize a pattern from limited input to rarer or differing environments for application – is when the researcher has the ability to control *exactly how poor* the stimulus is. To this end, we decided to conduct an experiment in which we taught a ludling to volunteer participants, controlling exactly what kind of data they would be learning from in the training session prior to testing for generalization.

We conducted an experiment in which participants were presented with an ambiguous rule involving trisyllabic sequences of nonce syllables: 123 → 321 (e.g. *ka.lei.bo* → *bo.lei.ka*). This transformation is compatible with at least four hypotheses:

(3) a. Invert the order of syllables

b. Exchange the first and last syllable

c. Exchange the final and antepenultimate syllable

d. Exchange every other syllable (i.e. σ_j with σ_{j+2})

These hypotheses differ in the instances or kinds of positions they explicitly name, e.g. first, last, antepenult. In principle, upon hearing 123 → 321, participants might have chosen any of the hypotheses in (3), all of which account the data. Importantly, these four hypotheses all diverge on their predictions for an input string in which there are tetrasyllabic inputs, as shown for the hypotheses in (3) in their respective order:

(4) a. Invert the order of syllables: 1234 → 4321

b. Exchange the first and last syllable 1234 → 4231

c. Exchange the final and antepenultimate syllable 1234 → 1432

d. Exchange every other syllable (i.e. σ_j with σ_{j+2}) 1234 → 3412

The hypotheses in (3c) & (3d) are unexpected based on the existing typology of ludlings. There are no extant precedence-modifying ludlings that refer to "penultimate" or "every other" syllable. There are two ways to interpret this typological lacuna. One is the result of a sampling error, e.g. the failure to find such a ludling due to not looking enough or having too small of a sample size in the world's languages. The other is that it represents a principled gap that is the result of an analytic bias (e.g. Universal Grammar), namely, that "penultimate" or "every other" syllable are predicates that are disfavored or disallowed in the construction of hypotheses that generalize to strings of different lengths. On the other hand, (3a) and (3b) are not only attested in surveys of precedence-modifying ludlings, they are built on primitives that recur time and again in linguistic structural descriptions. We turn briefly to a discussion of the importance of the predicates "first" and "last" syllable within the more general context of "edges of sequences".

Starting with Ebbinghaus (1885/1913), it has been acknowledged that not all positions in sequences behave in the same way: Items close to the sequence's edges (that is, in the first and the last position) seem to be remembered better than items in other positions. This effect, however, seems to have different subcomponents. Learners do not only remember *that* an item occurred in a sequence, but also *where* in the sequence it occurred; that is, they memorize also the *positions* of items. The memory for positions is most impressively illustrated by intrusion errors in memorization experiments (e.g., Conrad, 1960). In such mistakes, participants erroneously recall elements from another list than the one currently recalled; these intrusions, however, *often respect the positions in which they occurred in their original list*. It thus seems that participants memorize an item's abstract sequential position (e.g., Hicks, Hakes, & Young, 1966; Schulz, 1955). This and related research has revealed that

also the positions of items (and not only the identity of items themselves) are remembered better in edges than in other positions; accordingly, most recent models of memory for positions in sequences assume, in some form or another, that only edges have absolute positional codes, and that internal positions are encoded *relative* to the sequences' edges (e.g., Henson, 1998; Hitch et al., 1996; Ng & Maybery, 2002).

The importance of position-based memory in edge positions has been observed in several artificial grammar learning studies (e.g., Endress, Scholl, & Mehler, 2005; Endress & Mehler, submitted). One would expect, therefore, in ludling acquisition, that the most important positions are the first and the last one. Transformations where items in these positions are switched may thus be more acceptable than transformations involving reference to absolute or relative position of non-edge syllables. This would explain why transformations (3a) and (3b) are attested, while (3c) and (3d) are not. Moreover, if learners predominantly attend to the first and the last syllable, then even the choice between total reversal (3a) may not be much more acceptable than (3b). We will now investigate these predictions empirically.

2. Experiment 1

2.1 Materials and Method

2.1.1 Procedure

Participants were first informed that they would witness a Martian rite. In this rite, a chief Martian always pronounces a sentence, to which a subordinate Martian has to reply appropriately. Participants were also informed that these two Martians mastered the rite perfectly, and were instructed to try to figure out what the rite was about. Then, participants were presented with 25 trials, in which one synthesized voice (the chief Martian) pronounced a three syllable sequence and another synthesized voice (the subordinate Martian) replied with the same syllables but in reverse order.

After familiarization, participants were informed that they would witness the rite now with the chief Martian and another subordinate Martian who masters the rite less well. They were instructed to judge on a scale from 1 to 9 whether the new subordinate Martian's response conformed to the rules of the rite. They were instructed to press 1 if they were certain that the Martian's reply was wrong, 9 if they were certain that it was correct, and 5 if they were unsure. Then they completed 20 trials in which the chief

Martian uttered a four-syllable sequence, and the new subordinate Martian replied with the same syllables in one of four different orders. In five of the trials, he replied with a "natural" transformation. In five trials, this transformation was a complete inversion of the chief Martian's sequence; in other five trials only the first and the last syllable were switched, while the middle syllables remained in place (that is, the order was transformed from 1234 to 4231). In the other trials, the subordinate Martian replied with an "unnatural" transformation. Half of these transformations were of the form "1234→1432", and the remaining transformations "1234→ 3412".

2.1.2 Materials

All syllables were consonant-vowel (CV) syllables synthesized with the Mbrola speech synthesizer (Dutoit, Pagel, Pierret, Bataille, & Vreken, 1996). Segments had duration of 120 ms, except for the vowels in the first and the last syllable of each sequence, which were lengthened by 25% and 150%, respectively. The F0 of the first syllable was also increased by 25%; the standard F0 of the sequence was reached at 25% of the duration of the consonant of the second syllable. The chief Martian was synthesized using the *us1* diphone base and a standard F0 of 150 Hz. The first and the second subordinate Martians were synthesized using the *us2* diphone base with a standard F0 of 75 Hz, and the *us3* diphone base with a standard F0 of 100 Hz, respectively.

We used the consonants (in SAMPA transcription) p, t, k, b, d, g, f, s, tS, v, z, Z, m, n, l, r, j, w, h, and the vowels I, A, O, U, E, EI, AI, OI, aU. We generated all possible syllables, and selected different random subsets for familiarization and training. We imposed the additional constraint that syllables in a sequence could have no vowels or consonants in common.

2.2 Results

As shown in Figure 1, the ratings for natural transformations (M = 6.42, SD = 1.02) were significantly higher than for unnatural ones (M = 3.72, SD = 1.88), $F(1,11) = 20.43$, $p = 0.0009$. While natural transformations were rated significantly above 5 (the neutral point), $t(11) = 4.83$, $p = 0.0005$, unnatural ones were rated significantly below, $t(11) = 2.37$, $p = 0.037$[1].

The ratings (1234→4321: M = 6.72, SD = 1.53; 1234→4231: M = 6.12, SD = 1.20) did not differ significantly between the natural transformations,

[1] Throughout this report, t-tests are two-tailed and computed with a chance level of 5.

$F(1,11) = 1.25$, $p = 0.288$, ns; the ratings of the unnatural transformation (1234→1432: $M = 3.23$, $SD = 1.71$; 1234→3412: $M = 4.20$, $SD = 2.19$), in contrast, differed, $F(1,12) = 7.91$, $p = 0.017$.

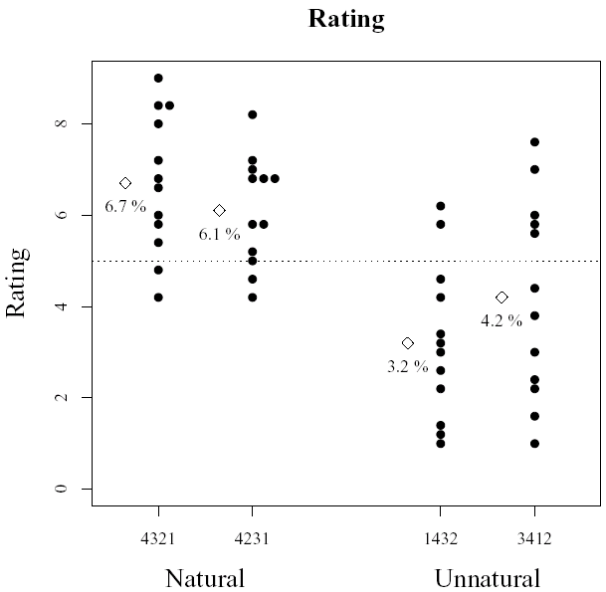

Figure 1: Results of Experiment 1.

2.3 Discussion

These results clearly establish that the "unnatural" hypotheses in (3c) and (3d) were not considered. There may have been a short-circuiting strategy that accounts for the numerical preference for (3d) over (3c).

One possible objection to our interpretation of these results is that they represent "general sequence learning" and do not bear on the specific question of primitives of linguistic representation. To examine this possibility directly, we replicated the experiment with musical stimuli. If musical sequence transformations are generalized differently than linguistic sequences, the interpretation that the results of Experiment 1 are language-specific is greatly bolstered.

3. Experiment 2

1.1 Materials and Method

1.1.1 Procedure

The procedure was identical to that in Experiment 1, except that tones instead of syllables were used as stimuli. Before familiarization, participants were informed that they would witness a Martian rite, in which the chief Martian played a short melody, and a subordinate Martian had to reply appropriately with another melody. Then participants were familiarized with 30 trials in which the chief Martian played a four-tone melody on an instrument, and the subordinate Martian played its inversion on another instrument. The rationale for using four-tone melodies rather than three-item sequences as in Experiment 1 was that participants usually encode intervals among tones rather than their absolute pitches; in terms of intervals, however, we used again three-item sequences.

After this familiarization, participants were again informed that they would now witness the rite with the chief Martian, and another subordinate Martian who mastered the rules of the rite less well; they were instructed to rate the new Martian's performance on a scale from 1 to 9. The chief Martian (that is, the same instrument as before) then played a five-tone melody comprising of 4 intervals (corresponding to the four-syllable sequences in Experiment 1). The new subordinate Martian then played a transformed melody in which the *interval order* (rather than the tone order) was transformed. Moreover, since intervals are inverted when played backward (e.g., an upward octave becomes a downward octave), the intervals were also inverted. Again, the two natural transformations were 1234→4321 and 1234→4231, and the two unnatural transformations 1234→1432 and 1234→ 3412. Each transformation occurred five times in the test items.

1.1.2 Materials

Stimuli were generated as MIDI files using abc2midi (http://abc.sourceforge.net), and then converted to aiff files using timidity^{++} (http://timidity.sourceforge.net). The melodies played by the chief Martian comprised the 24 semitones of the octaves from C_4 to C_6, and were generated by randomly choosing tones from this range. Since these were randomly chosen tone levels, the likelihood of a higher-level grouping into a chord is minimized. The first subordinate Martian played the exact inversions of these melodies. Some of the transformations by the

second subordinate Martian used a slightly larger pitch range, because they were not the exact reversals.
Tones had a duration of 250 ms. The chief Martian was implemented using timidity[++] MIDI code 52, while the two subordinate Martians were implemented using codes 98 and 82, respectively.

1.2 Results

As shown in Figure 2, participants rated the natural transformations (M = 4.89, SD = 1.24) better than the unnatural ones (M = 4.17, SD = 1.18), $F(1,12) = 11.96$, $p = 0.006$. Participants rated the complete reversal (M = 5.46, SD = 1.47) better than the transformation 1234→4231 (M = 4.32, SD = 1.56), $F(1,12) = 5.70$, $p = 0.034$ and better than all other three as a group, $F(1,12) = 10.22$, $p = 0.0077$. Moreover, while the complete reversal was rated better than all other transformations (against 1234→4231: $t(12) = 2.39$, $p = 0.0343$; against 1234→1432: $t(12) = 4.05$, $p = 0.0016$; against 1234→3412: $t(12) = 2.33$, $p = 0.0380$), no other pair-wise differences were significant.

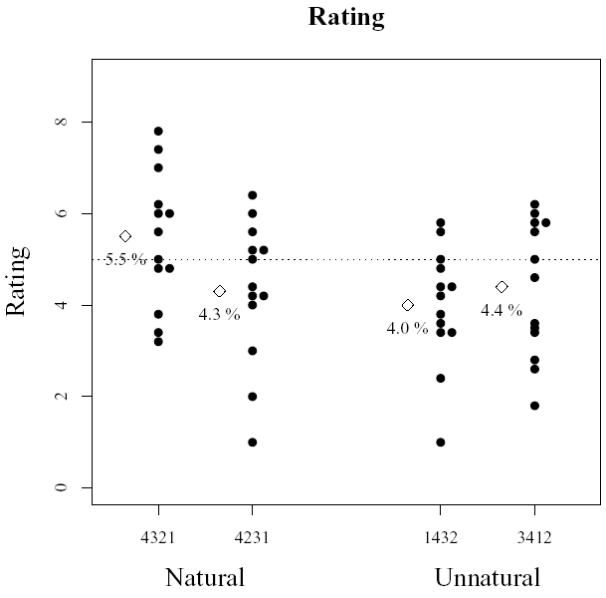

Figure 2: Results of Experiment 2.

1.3 Discussion

When considered in light of the results of Experiment 1, the results of Experiment 2 suggest that musical sequence transformations are not learned the same way as linguistic transformations. One possible explanation is that melodies (in particular atonal ones such as the melodies used here) may be encoded predominantly with respect to their *contours* (e.g., Dowling & Fujitani, 1971); since all but transformation (1a) change the contour, one may expect that only transformation (1a) should be acceptable. Possibly, one may observe similar results using linguistic material that also features prosodic contours (e.g. suprasegmental tones). However, the question may also be turned around to ask why edges are special in language but not music. While syllables bear intrinsic properties (such as their segmental content), musical notes largely function solely as links in a contour. While future research may reveal whether the analytic biases for edges in linguistic computation found in Experiment 1 follow from more basic representational properties of sequence learning, the fact that they did not emerge in Experiment 2 would suggest that it is words or syllables in particular that implicate a domain-specific learning bias (Gallistel, 2000).

2. Conclusion

Jointly considered, the experiments here allow one to conclude that (a) not every logically possible generalization is actually followed by humans when learning syllable-precedence-modifying ludlings, and (b) the possibility of edge-switch as the generalization may be unique to linguistic computation. Taken in tandem these two conclusions implicate an analytic bias towards using only certain types of elements in the structural description of syllable-level generalizations -- namely left edge, right edge, and ∀ (all syllables in the domain) – which coincides with the typology of existing natural ludlings. Not every way of generalizing a pattern is equally likely, which arguably is a relief for the learner in the face of representationally ambiguous data.

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