Chapter 13: The study of syntactic cycles as an experimental science

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Historical cycles in the syntactic expressions of particular functions (e.g., negation) exemplify a dynamic competition between distinct representational architectural constraints. We study these constraints in an experimentally controllable synchronic paradigm, using situated artificial language learning to induce syntactic cycles. Adults and children learn to use different languages in production and comprehension. The languages appear with frequency-controlled variability in alternate forms with a directionality that the representational architectural constraints predict. Each subject's learned output is the training input of the next, to accelerate syntactic changes. Questions include: do learners pick up new usage patterns in the predicted cyclical direction; do children change their usage in the predicted direction faster or with weaker frequency bias than adults; what is the relation between emerging changes in language usage and grammaticality intuitions? This research program offers detailed information about cyclic transitions that can enrich an understanding of historical data. Most important, it can give direct experimental confirmation of the dynamic presence of the architectural constraints proposed as the cause of historical cycles.

Introduction

The study of language histories has served the field of theoretical linguistics by taking historical changes as the effects of dynamic inner constraints on possible languages that create the changes. Of great interest for linguistic theory is the discovery that certain kinds of patterns of change are repetitive: in the simplest case, a particular language structure type 1, becomes type 2, and then type 1 again, and then type 2…etc. These are known as "historical cycles", described in other chapters in this volume.[1]

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[1] Abbreviations include: HPP = Head Preference Principle; LMP = Late Merge Principle: CFP = Clitic Formation Principle; FRP = Functional Recovery Principle; ALL = Artificial Language Learning; sALL = Situated Artificial Language Learning.

Van Gelderen is a principal in creating a syntactic architectural theory of why the cycles exist – essentially a dynamic between two kinds of representational constraints in syntax. The important underlying theme is that at any given time, specific constructions in the overt syntactic structure of a language reflect a computational *compromise* between the different constraints on linguistic representations. Over time, one constraint dominates or replaces the other, and then is dominated or replaced by the other, resulting in the overt historical cycle. Typical overt cycles are seen in negation, agreement systems, pronominal systems, tense systems and other functional constructions.

The child learner is parent to the adult language. Thus, we are interested in understanding the language constraints and learning dynamics in the individual language learner that result in the cycles of language change. The logic underlying our program is this:

(1) a. the language learner is the dominant force in re-analyzing his/her language

b. historical cycles demonstrate the competition of different architectural principles of syntactic representations.

c. the competing architectural principles must be available to the learner

Thus, the historical facts motivate a dynamic architectural theory, which in turn must claim that the dynamic is part of the language learner's cognitive and linguistic repertoire. The problem we address here is how to study the learner's access to the architectural principles in a more direct way than delineating the historical cycles. That is, we would like to find *synchronic* evidence that the child indeed applies the competing architectural constraints as s/he learns the language.

Below, we outline how we are using a naturalistic, "situated" artificial language paradigm and transmission of language training across "generations" of learners to study experimentally the dynamics of language change. It is critical that the paradigm can be used with children who are still in the normal language learning age range. The kernel of the idea is first that we can structure the artificial language to be intermediate between different historically attested cycles, and examine which direction the language is changed by the learners as they make and transmit errors. Secondly, we can manipulate the dynamics of how the training is presented, presenting critical examples in different ways, to illuminate how the individual learner interacts with the data and imposes constraints on it. Finally, we can probe the relationship between learning to *use* a new grammar as knowledge shifts from one stage to another, with the emergence of *grammaticality intuitions* about the new structures. This affords a unique opportunity to study the relation between usage and intuitive categorical knowledge in a controlled setting.

We first review salient aspects of van Gelderen's proposals, current practice in artificial language learning, and recent artificial language studies of compressing the "evolution" of language. Then we introduce our paradigm and some sample studies.

The reader should note that the application of sALL to the study of "synchronic cycles" was sparked by the recent conference that resulted in this volume. We have created the paradigm and are piloting studies but we do not yet have definitive data. Thus, the initial goal of this paper is to outline the logic of the prediction that historical cycles make for the language learner, and to present a method for studying those predictions.

1. The Economy of Language Change

Van Gelderen (2006, 2008) proposes that two minimalist principles of computational efficiency and locality largely drive syntactic change in conjunction with a cyclic process of phonological weakening and strengthening. The reader will be aware that van Gelderen's theory of reference is the minimalist program, although the principles she adduces may be stateable in other frameworks. We do not dwell on the theoretical background here, the reader is again invited to consult the other papers in this volume. The principles are:

Head Preference Principle (HPP): *Material in head positions is more structurally accessible for feature checking compared to Spec-head checking.* The typical result historically is that a double-marked process, e.g., for negation, which has to be analyzed as **Spec+head**, collapses to a single process, allowing analysis of the head without **Spec**.

Late Merge Principle (LMP) Lexical insertion (external merge) is preferred *in situ* rather than requiring "move" (or "copying", internal merge). Typically, a lexical item in an embedded part of a phrase (*e.g.,* in the VP) which moves (or is copied) outside of the phrase becomes directly inserted in its final position and takes on properties of a function word. [e.g., "nothing" inside a VP, becomes "not" outside the VP). The associated result is that the word that originally required a theta role, now becomes a pure "syntactic" word without a theta role.

Two additional well-attested principles play a critical role in interacting with these principals in the dynamics of historical change.

Clitic Formation Principle (CFP) Functional elements with primarily formal content, become incorporated phonologically as components of head phrases.

Functional Recoverability Principle (FRP). Functional elements must be sufficiently clear phonologically to trigger distinct computational processes.

While learnable and economically constrained by the first two principles, the usability of a grammar they motivate may suffer through reduced phonological clarity as the function word becomes a clitic, thereby reducing its recoverability (e.g., /nOt/ goes to /nt/). This can motivate the adoption of new elements to reinforce the increasingly phonologically weak marker to make sure there is functional recoverability. As additional elements (*e.g.* double negatives) appear, the cycle begins again. For example, consider, a canonical example of language change studied by Jespersen (1917), in Germanic languages (stated for English, following van Gelderen, 2008) (Figure 1).

L1-L3 depict possible NegP constituents at various stages of the negative cycle.

At the L2 stage *no thing* becomes a grammaticalized negative marker, *noght*, and the phonologically weak negative marker *ne* gradually becomes a clitic, leaving an empty head under NegP. In L3, this position is filled with *not*, formerly in Spec, according to the HPP. Roughly at the same time, *noghi* (as a negative marker) weakens phonologically to *not(n't)*. The weakening eventually prompts the appearance of a new reinforcing element and the cycle begins again. This aspect of the cycle can be seen in those modern dialects of English that permit double negatives.

Jespersen's Cycle of historical changes in the negative construction is a classic and well-studied example of syntactic change. The evidence in general for syntactic cycles comes largely from incomplete historical texts, making difficult an empirical investigation of the underlying driving factors, such as van Gelderen's hypothesized economy principles. Even the full negative cycle--portions of which are well-attested cross-linguistically-- has not been completely documented in a single coherent historical model (Dahl, 1979).

The critical feature of van Gelderen's ideas is the particular principles; the historical data serve as confirmation of them: thus, the incompleteness of historical data is not a crippling problem, since complete prediction of the historical changes is not intrinsically required by the claim that they result from the interaction of the particular structural constraints. However, it will be useful to be able to test the principles actively rather than being dependent on incomplete historical records. To that end, we are applying a naturalistic paradigm for "situated" artificial language learning that can then be used with adults and children to test the effect of the theoretical principles. Below we discuss some background involving artificial language learning. We then present our new paradigm and examples of how it may be used to test the synchronic principles that have been proposed to explain the diachronic cycles.

2. Artificial Language Learning and Change

In this section, we discuss artificial language learning in general, how it has been applied to language change, and some criticisms of the traditional paradigm.

2.1 Artificial Language Learning

In the more experimental areas of linguistic inquiry, artificial language learning (ALL) paradigms have been used to study conditions on language learnability and processing mechanisms. ALL paradigms have four salient features:

(2) a. the structure of the grammar to be learned;

b. the way the evidence is presented to the subjects;

c. the discriminative response expected from the subjects to show learning.

d. the motive to learn the grammar.

In the most basic of these paradigms, a subject is passively exposed to strings generated by some form of a grammar (often finite state). After some training period, the subject's ability to distinguish novel strings generated by the target grammar from ungrammatical strings is tested using a head-turn or listening time preference paradigm (in the case of infants; cf Kemler Nelson et al., 1995; Gómez & Gerken, 1999). In the case of adults, a standard procedure is to present examples of grammatical strings and then to assess learning through explicit grammaticality or recognition judgments (Reber, 1969). Procedures like these are limited to tests of simple pattern-recognition ability, usually of grammars with simple formal structure; attempts to teach passive subjects more complex grammars have been generally unsuccessful.

Subjects can learn to make grammaticality judgments on more complex grammars, including simple context-free grammars, when explicit instruction is provided. In this version of the paradigm, a subject is presented with a series of grammatical and ungrammatical strings and makes grammaticality judgment in response to each, receiving explicit feedback after each trial (cf. Friederici et al,, 2006)

In a very small number of cases, subjects are taught to use the language in some way, without being given explicit instruction in grammaticality – rather, their successful use is dependent on creating or understanding or extending sequences with correct grammatical knowledge (Bever and Hansen, 1988). Perhaps the most natural procedure of training and learning an artificial language to date is that introduced by Friederici et al (2002). Their ultimate goal involved examining brain activation patterns when making grammaticality judgments about the artificial language they have learned. Their language "Brocanto", had 14 words that characterize a small set of objects, verbs and locations in a matrix of locations on a screen. The language was interesting in that it included "moves" that objects could make from one location to another on the screen. Learning was inculcated by having subjects work in pairs, in which each subject had to tell the other the move s/he had just made in Brocanto, and the other subject had to make the corresponding move on hiser display. In this way, Friederici et al captured many aspects of normal language learning: notably, subjects were motivated by the need to communicate, subjects received both production and comprehension experience, and the communication was entirely verbal (with automatic computer correction of errors). (Subsequently, Morgan et al have used a variant of Brocanto, but with subjects trained individually in separate training blocks with feedback for production and comprehension, as in Bever and Hansen.)

2.2 ALL Studies of Language Change

Over the past decade, a number of computational models have been developed in support of the idea that language 'evolves' as an adaptive means of transmitting cultural information through successive generations. These iterated learning models (ILMs), have recently been brought into the realm of behavioral experimentation using an ALL paradigm (Kirby, Cornish & Smith, 2008). Kirby et al. draw ambitious conclusions from these experiments about mechanisms for the original evolution of language, which are not immediately relevant to our research. But their methodology may be useful when applied to a more grounded study of the dynamics involved in syntactic change.

Kirby and colleagues use a recursive multi-generation paradigm, paralleling the prior simulations, in which subjects are instructed in a language as generated by a previous participant under the guise of learning alien descriptions for simple moving objects. Each subject passively views a number of picture-string pairings and is then called on to produce strings for a set of test pictures (half of which were previously seen by the subject). Starting from completely random picture-string pairs, the first few subjects face an impossible memory task and, as may be expected, produce a number of recall/transcription errors. Eventually, the strings given for novel pictures are the product of innovative systematization of various kinds that simplify learning and retention. The subject's pairings, including any errors, are then passed to the next "generation" of learners (i.e. the next subject in the experiment). The general result of these studies is to show that subjects tend to create paradigmatic "morphology" out of systematic errors in learning, memory and transmission to succeeding subjects. The final state of the iterative process generally looks like classic paradigms of a morphologically rich sub-language, in which individual sub-components of "words" are systematically related to particular objects or particular kinds of motions. In other words, over successive mis-learnings and mis-recalls, subjects converge on a componential relation between the words and what they refer to.

Kirby et al. argue that this is a miniature replication of how language might have evolved. This is an ambitious interpretation of what is justified by their subjects "item-and-arrangement" solution to an otherwise impossible learning problem. But for our purposes, their method has pioneered a way to hasten the impact of formal constraints on possible languages on changes in time: as subjects learn what they can, and that becomes the model for the next set of subjects to learn from, we can trace dynamic changes in the linguistic structure itself.

Hudson-Kam & Newport (2005) study the acquisition aspect of language change, with particular focus on the regularization of creoles. In this paradigm, participants are instructed in artificial VSO languages containing various degrees of unpredictable variation in the use of determiners as part of **N + Det** structures. The degree of variation had no effect on the ability of participants to learn vocabulary or make forced-choice grammaticality judgments. In a sentence completion task, however, children (mean age 6;4.10), but not adults, regularized determiner usage (or non-usage). It is hard to pin down how much of the training involved natural features, but the sentence completion task certainly recruited both comprehension and production processes.

2.3 Criticism of Traditional ALL Paradigms

Consider a broad outline of the circumstances in which children usually acquire knowledge of a language and grammaticality sense. The terms mentioned in (2) characterize and differentiate ALL paradigms. In (3), more detail is provided.

(3) a. *The structure of the grammar to be learned*. This of course, is the subject of linguistic investigations and theories with many conflicting ideas and proposals. Yet, several features endure across many different linguistic theories: sentences are a natural unit of complete meanings, with structure and meaning compositionally derived from their constituent phrases; sentences have derivations, relating inner (aka 'logical') form to outer structures and phrasal sequences.

b. *The way the evidence is presented to the subjects*. Children characteristically hear language in its natural use, not a formal or didactic setting with strictly grammatical sentences correctly applied. They hear fragmentary sentences, optional variation in particular constructions, and outright ungrammatical sequences that are nonetheless communicatively effective. Most important, the language exposure is "open ended" in the sense that there is no formally circumscribed domain of discourse: at the same time, there is usually a set of focal topics with a good deal of repetition both of content and form.

c. *The discriminative response expected from the subjects*. As they grow up, children are expected to pronounce their language correctly, to understand the sentences appropriately, and to speak in a natural way. They are *not* required to speak strictly grammatically, nor are they required to understand only grammatically correct and complete utterances. Rather, they are expected to speak and understand with the same variability, appropriateness and correctness as adults. Most important may be the fact that they are required not only to understand sentences but also to produce them as part of their natural language behavior.

d. *The motive to learn the grammar.* This is the most vexed and controversial of matters in the relevant fields. The simplest functionalist answer is that learning the grammar is the best vehicle for achieving what is required in (c): that is, speaking and understanding fragmentary and sometimes ungrammatical sequences as well as grammatical sentences may be best facilitated via knowledge of the correct structures, and then behavioral habits that deviate from them in standardized ways. The simplest structuralist/nativist answer is that the child is predisposed to learn particular kinds of grammatical structures, with great filtering power over the apparent variability in its linguistic experience. In a general sense, both approaches to the problem may be true, since they tend to complement each other. A different kind of model has been suggested by Bever, namely that the abstract grammar is acquired by individual children, one at a time, because it reconciles conflicting representations between what the child can say and what it can understand: in this sense, the language structure presents a canonical problem of the kind that humans like to solve: that is, learning the abstract grammar is intrinsically mental fun. (Bever, 1975, 1992, 2009).

In light of these characteristics of natural language learning, ALL paradigms necessarily place subjects in an unnatural learning situation. The most problematic aspect of the paradigm is the usual focus on grammaticality judgments, a rather sophisticated behavior that children are rarely explicitly taught. By explicitly teaching grammaticality judgments, these paradigms shortcut the mechanism through which the ability to make such judgments naturally appears, with unknown consequences for the internal grammatical representation. The lack of semantic context and production in many other ALL paradigms preclude their use for any serious study of language change (but note Friederici et al, 2002, which does capture many natural features).

Dulany, Carlson & Dewey (1984; also Perruchet & Pacteau, 1990) provide evidence that the basic ALL paradigm does not produce (or at least does not measure) unified internal grammars. In these experiments, subjects provided explicit information about their grammaticality judgments, as by indicating where an ungrammaticality occurred in a string of letters. Explicit judgments were highly predictive of performance when the ungrammaticality was the result of a simple pattern violation, such as an illegal bigram. Subjects were unable to articulate more complex violations or violations of multiple simple rules. These failures of explicit knowledge were closely correlated with chance performance, suggesting that explicit knowledge often drives ALL performance. Natural language competence, in contrast, is to some extent disassociated from explicit knowledge and requires a more coherent knowledge (conscious or unconscious) of the grammar.

A few of the paradigms we have reviewed mitigate the drawbacks of ALL in one way or another. The Kirby et al. paradigm, in which subjects basically tell and then retell simple utterances, involves creating “natural” errors and variability in what successive subjects experience. Yet the paradigm is relatively artificial in how the stimuli are presented, and the range of contents. The Hudson et al studies involve actual situations, experimenter-controlled variability in the critical data the child experiences and a relatively natural response (completing sentence fragments). It is also relatively unusual in using auditory and verbal activity rather than displayed or typed texts. Yet an important virtue of the paradigm also limits its use: subjects are in a real person-to-person context with natural responses possible and studying young children, still in the normal first-language-learning age range. This requires time-consuming video analysis of data instance by instance, with loss of much information and requiring inter-judge reliability measures. Friederici et al (2002) come closest to a paradigm that is natural in relevant ways. We will now discuss an alternative which combines some virtues from Bever and Hansen, Friederici et al and Kirby et als' methodologies.

3. Situated Artificial Language Learning

Our goal is a paradigm that captures certain essential properties of ALL methods that will make it possible to study dynamics of learning and language change in children, with a relatively natural auditory/verbal learning situation.

To this end, we have developed a novel ALL paradigm, "situated ALL" (sALL), that allows us to study links between language use and grammar acquisition. Our initial results show that moderately sophisticated grammars can be learned through usage in an experimental setting and demonstrate the predicted importance of integrating perception and production in learning.

The main feature of the sALL paradigm is semantic context in the form of a simple 2-dimensional visual world (a sample display is shown in Figure 2). Using our custom software, subjects can freely create and move geometric shapes on the screen and change any of several visual attributes. A corresponding phrase structure grammar (e.g. Figure 3) can be used to provide a linguistic description of a given visual arrangement, specifying the appearance of each shape and their spatial relation to one another. For example, the sentence

(4) red star solid green triangle dotted te yellow diamond left-of above

the solid, red star is above the dotted green triangle that is left of the yellow diamond

describes the arrangement in Figure 4 using the grammar in Figure 3. After a short practice session (creating arrangements from English instructions), subjects become proficient in the use of the software.

In a typical experimental session, a subject is pseudo-randomly presented with either a sentence from the target grammar (displayed on screen or spoken through headphones) or a visual world. The subject is then prompted to produce a corresponding world or sentence. In the most natural case, linguistic stimuli are spoken via the MaryTTS text-to-speech system (Schröder & Trouvain, 2003) and responses are verbal, processed by speech-recognition software with a limited vocabulary (Dragon Naturally Speaking). The visual world is manipulated using a touch screen display, allowing for a minimal technology barrier.

After responding, a correct response is presented. These mapping trials constitute the training portion of the experiment and provide a continual measure of production and comprehension performance. Competence is periodically probed through grammaticality judgment trials. On these trials, a novel sentence is presented in isolation and the subject is prompted to judge whether or not the sentence is possible in the learned language. No feedback is given.

Bever & Hansen (1988) used a very simple version of a similar paradigm to examine the role of bidirectional language usage in grammatical induction. Subjects participated in a production-only (picture->sentence), comprehension-only (sentence->picture) or mixed condition. Subjects in the mixed condition show markedly higher performance on production trials (Figure 5), despite receiving half the production training of those subjects in the production-only condition, and in making grammaticality judgments (Figure 6). These results support the hypothesis that bidirectional language usage facilitates the development of structural representations. The change in mapping performance also suggests a transfer effect between language comprehension and production which is modulated by the emerging grammatical representations (see Bever, 1975, 1992, 2008).

Earlier studies and our streamlined paradigm open up the possibility that we can adapt it to study the basic principles that have been supported by diachronic syntactic cycles. The new version of the paradigm is one that children can master, indeed may do much better than adults, using the verbal input and output facilities. There are many uses for this paradigm, including sophisticated studies of neurological organization of different kinds of grammars with different kinds of training regimes. The new questions for the concerns of this paper are:

(5) a. Can we replicate diachronic cycles synchronically?

b. Can we elucidate with more detail than allowed from the historical data, the basic principles that constrain the cycles?

c. Will the progressive direction of the cycles depend in part on both comprehension and production experience?

d. How will the change in grammatical structure use be reflected in elicited grammaticality judgments.

e. Are children under ten more likely than adults to respond categorically and rapidly go through cycles?

In considering how the sALL paradigm might be used to study syntactic cycles and grammaticalization, we adopt van Gelderen's (2008) theoretical framework of syntactic cycles as a dynamic process stemming from conflicting constraints.

One possible methodology for studying a cycle like the classic negative one follows Hudson-Kam and Newport (2005), presenting variable mixtures of negative forms on comprehension trials and examining the corresponding frequencies on the production side. As discussed above, our paradigm is suitable for use with children, where any cyclic shift should be most apparent. This method can be extended and possibly sharpened by applying a paradigm like that of Kirby et al, in which the input data to each subject is the final stage of output from a prior subject.

The introduction of variability drawn from different stages of a cycle is critical to our synchronic studies. First, we cannot expect subjects to spontaneously develop "errors" in the direction of or against a cycle in such a short time – historical cycles develop over many generations of learning and adult use. Second, we can calibrate the effect of directionality by manipulating the relative frequencies of the alternate variants of a cycle – we can expect that the frequency of alternate forms that move in the predicted direction can be lower and have an effect than the frequency of alternate forms that move against the predicted direction. That gives us a quantitative tool to compare adults and children. All subjects may shift in the predicted direction to some extent, but we predict that the balance of alternate forward and backward forms that shift children in the predicted direction will be less extreme than for adults.

A separate feature of our paradigm is that we can contrast changes in language behavior patterns governed by cycles against corresponding changes in grammaticality intuitions. This will allow us to investigate the dynamic relation between gradual shifts in artificially induced 'dialects' against shifts in grammatical representations. The proposed experiment illustrates an empirical approach to historical cycles, using the negative cycle as a convenient and well-understood example, but the paradigm has a straightforward application to virtually any other cycle. The basic principle comes from the Hudson, Kam & Newport study, namely that learners (at least children) will tend to reduce variation during production. In the Hudson, Kam & Newport study, this behavior is likely the result of general learning mechanisms. Here, we introduce economy factors that should amplify (or dampen) the regularization effect. The training set (presented as a mixture of production/comprehension trials) conceptually consists of three languages, corresponding to the three stages of the negative cycle. Two-thirds of the relevant training sentences use negative constructions; two-thirds show one of three non-cyclic variations [e.g. case marking?] (control languages). The overlapping sentences are fully crossed control markings and negative constructions with equal frequency for each combination. The frequency of each construction for each experimental condition is given in Table 1.

	Basic Word Order	Mixture (%)

		Forward (Forward')	Equal	Reverse (Reverse')
L1	N N Neg V (Neg)	4.7	11	19
L2	N N (Neg) V [(Adv) Neg]	9.5	11	9.5
L3	N N V Neg	19	11	4.7
Control 1		4.7 (19)	11	19 (4.7)
Control 2		9.5	11	9.5
Control 3		19 (4.7)	11	4.7 (19)
$\text{Control}_{1,2,3} \times \text{L}_{1,2,3}$		3.7	3.7	3.7

Table 1: Experimental language mixtures.

The Forward condition (and Forward', which reverses the control mixtures) tests the tendency for the negative cycle to progress in the canonical direction. The Equal condition serves as a control with respect to the control constructions (presented with equal frequency) and measures any tendency for the cycle to progress in the absence of frequency differences. The Reverse (and Reverse', again reversing the control mixtures) condition allows the unidirectionality of the cycle to be tested. Subjects will be trained to an acceptable level of performance (note that any of the possible negative and control constructions will be acceptable on production trials). Following criterion, critical test production trials eliciting negative and marked constructions will be given.

The variability in case marking provides a control and baseline of regularization. Based on the results of Hudson Kam & Newport, adult participants should show a pattern of probability matching, rather than regularization, for case marking. The same behavior may be seen for negation, although a change in negative construction probabilities would be suggestive.

Children should reduce variability in both the negation and case marking aspects of the language. A change in case marking probabilities should be purely the result of regularization; a differential change in negation probabilities would suggest that non-statistical factors influence their distribution. Support for this can also be obtained by comparing the regularization towards L3 in the forward condition to L1 in the reverse condition. According to the economy explanation, L1->L2->L3 is the logical (and attested) ordering of the cycle. The L3->L2->L1 order is uneconomical since L3->L2 goes against the HPP and L2->L1 against the LMP.

The production frequency shift is modeled as a function of regularization, grammaticalization and their interaction. From a regression perspective:

$$f(L_i) \approx \beta_1 \mathbf{R}(\mathbf{f}(\mathbf{L})) + \beta_2 \mathbf{G}(\mathbf{f}(\mathbf{L})) + \beta_3 \mathbf{R}(\mathbf{f}(\mathbf{L}))\mathbf{G}(\mathbf{f}(\mathbf{L})) + e$$

where R and G are regularization and grammaticalization functions, respectively. The use of the control constructions provides an important baseline against which the effect of grammaticalization beyond the tendency for regularization can be determined.

We can also deploy this paradigm in a version with successive subjects, following Kirby et al, to track the evolution of the different ways to express negation. Given the auditory/verbal manipulation we may be able even to enhance the cliticization of certain forms by pressuring subjects to speak quickly.

Much of this is conceptual at the moment, and, of course, this particular experiment involves negation, which English speaking subjects have already learned in a form related to the historical variations. We can also use the paradigm with colleagues in countries with non Indo-European native languages (e.g., Chinese) to neutralize the impact of directly related prior language experience. We will now give an outline of an experiment with a less attested cycle involving features not indigenous to English syntax.

A different way to test the principles with English speaking subjects is to construct a cycle that could exist following the architectural principles, using a syntactic/semantic feature that does not play a role in English syntax. Consider for example, the relation between telicity, unaccusativity and reflexives, which does play a role in many other languages (*e.g.*, Spanish: Tenny, 1987, Sanz, 2000). The sALL paradigm does allow for presentations and productions of different kinds of motions. For example, it can represent "explode" as a telic mono-argument predicate (aka "unaccusative") with a specific end point in time by showing an objects actually explode visually: and "bounce" can be depicted as an atelic mono-argument without specific end points by having an object bouncing for the duration of the display (in sALL the depictions are actually dynamic, but Figures 7 and 8 represent them statically for this paper).

We can construct a cycle, regardless of actual historical facts of English as to how telicity is marked, although there may be some evidence of actual cycles of this sort historically in the background of languages other than English. The different single-argument telic constructions would look like the sequence in (9), in order of change (the examples use actual English-like words for exposition, but in an sALL paradigm will be nonsense words). The kinds of cases that we can present to subjects with differing probabilities are based on the following fictitious but theoretically motivated cycle.

Figure 9 depicts a cycle analogous to the negative cycle. In L1 an additional supportive word merges out of the VP to support the weakened clitic marker.

(6) the circle s[+telic]'exploded itself[+telic]

Weakening continues and the support word becomes in incorporated under Spec in L2. In L3 the clitic has disappeared and the support word appears in head.

(7) the circle exploded (it)self[+telic].

The cycle of cliticization and recoverability continues back to L1. The language also includes evidence for the transitive construction.

(8) the square exploded the circle

The actual experimental paradigms based on this cycle can be organized in the same way as for the negative cycle example: subjects are presented with mixed cases that vary in the relative frequency of the adjacent construction types. The same experimental paradigm variants can be used to study the relative learning and directionality of mistakes, as well as paradigms that involve taking the learned output of one subject and using it as the training input for the next.

We should note that while this cycle follows the architectural principles, it does not enjoy as much historical justification as many others. We find that to be a virtue – testing a cycle that *should* exist, but may be rare. Other, well attested cycles that are novel for English include subject/object agreement, and the copula cycle.

4. Conclusion

This paper demonstrates how we can expand the empirical support for the structural principles proposed by van Gelderen. Our approach promises to supplement scattered historical data with synchronic experimentally replicable research. The outcome will be to verify the presence and dynamic competition of the structural principles. It will be of considerable significance if children impose the cycles relative to non-cyclic control structures and adults do not: this will lend further confirmation of the idea that the underlying architectural principles that result in cycles are part of the language learning child's structural repertoire. An additional benefit may be that the paradigm allows for detailed analysis of "micro-steps" in the experimentally-induced miniature evolution of the cycles: this can sharpen the search for details in actual historical cycles that have hitherto been unnoticed. Finally, the data for actual cycles is based largely on documented usage, not grammaticality intuitions: we will be able to compare shifts in usage against shifts in grammaticality. This may give detailed insight into how shifts in usage emerge as shifts in grammatical representations. Since linguistic science at its best rests on accounting for details, this research may make some unexpected contributions to the field of historical linguistics and linguistic theory in general.

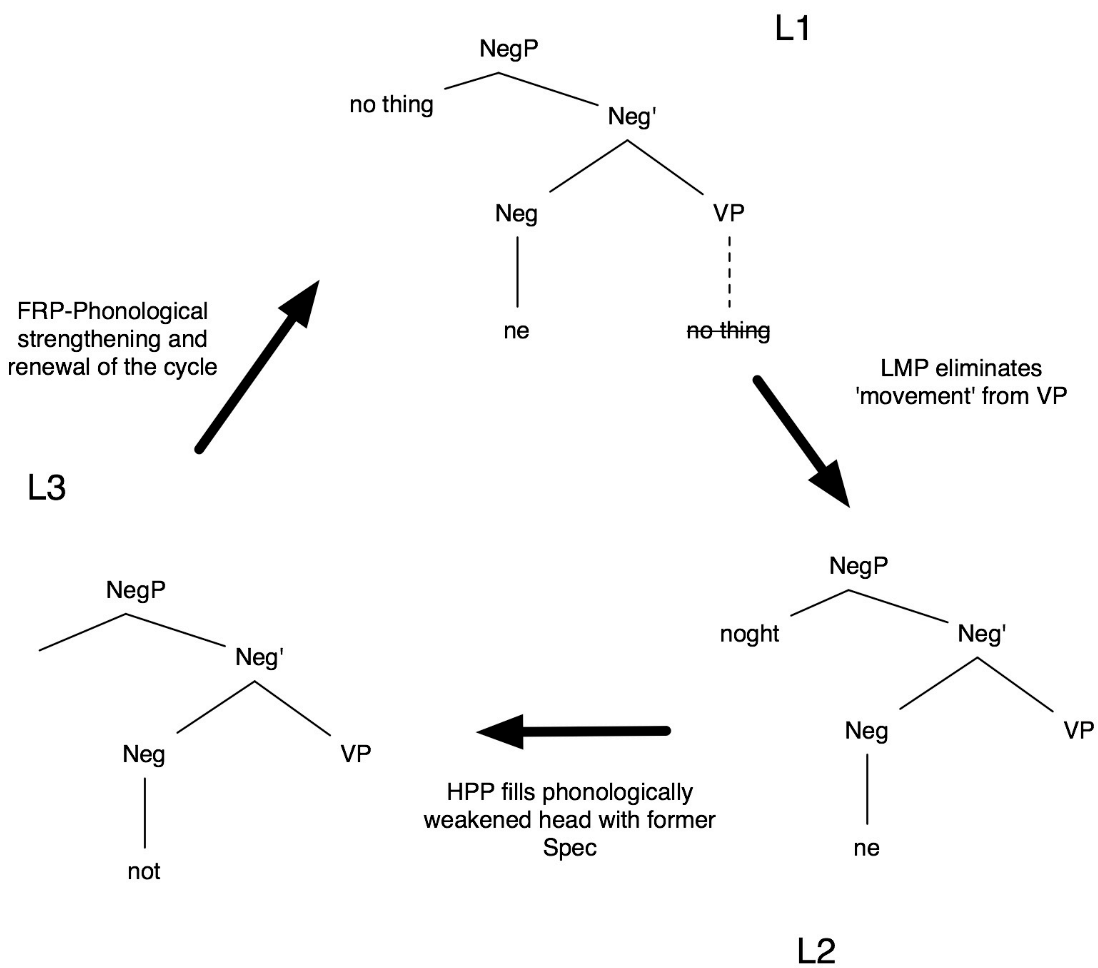

Figure 1. *The negative cycle.*

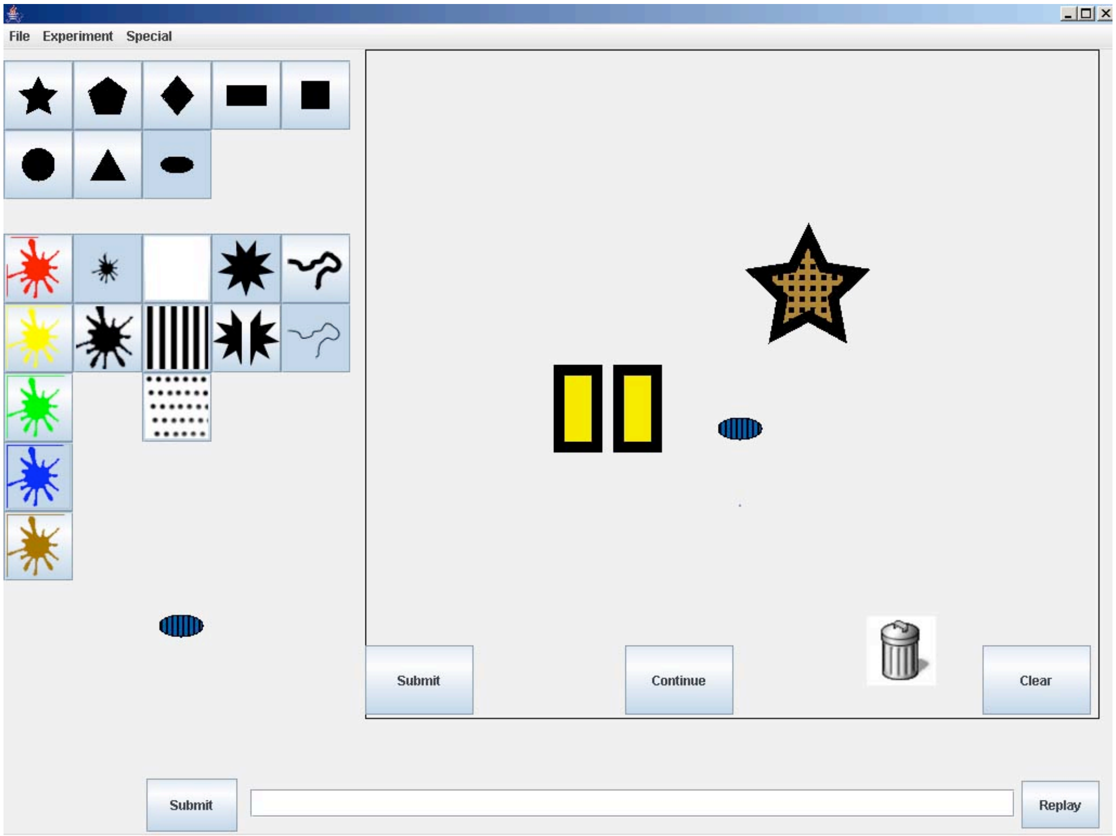

Figure 2. *Sample computer interface presented to subjects.*

S → NP Pred
NP → (ADJ) Noun (Size) (Pattern) (Clause)
Clause → te Pred
Pred → ADJ
Pred → NP Rel
Pred → NP NegP
Noun → {square, rectangle, star, pentagon,
diamond, triangle}
Size → {small, medium, large}
Pattern → {striped, dotted, solid}
ADJ → {red, yellow, green, blue, purple, thick, thin, whole, cutout}
Rel → {above, below, left-of, right-of, behind,
infront-of}

L1 NegP → ne Rel (NOT)
Noun→{..., nothing, anything}
L2 NegP → (ne) Rel (Adv) NOT
L3 NegP → Rel NOT

Anderson (1975)

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Figure 3. *Rules for three simple artificial languages. Each language contains the basic rules and one of the last three rules for negation.*

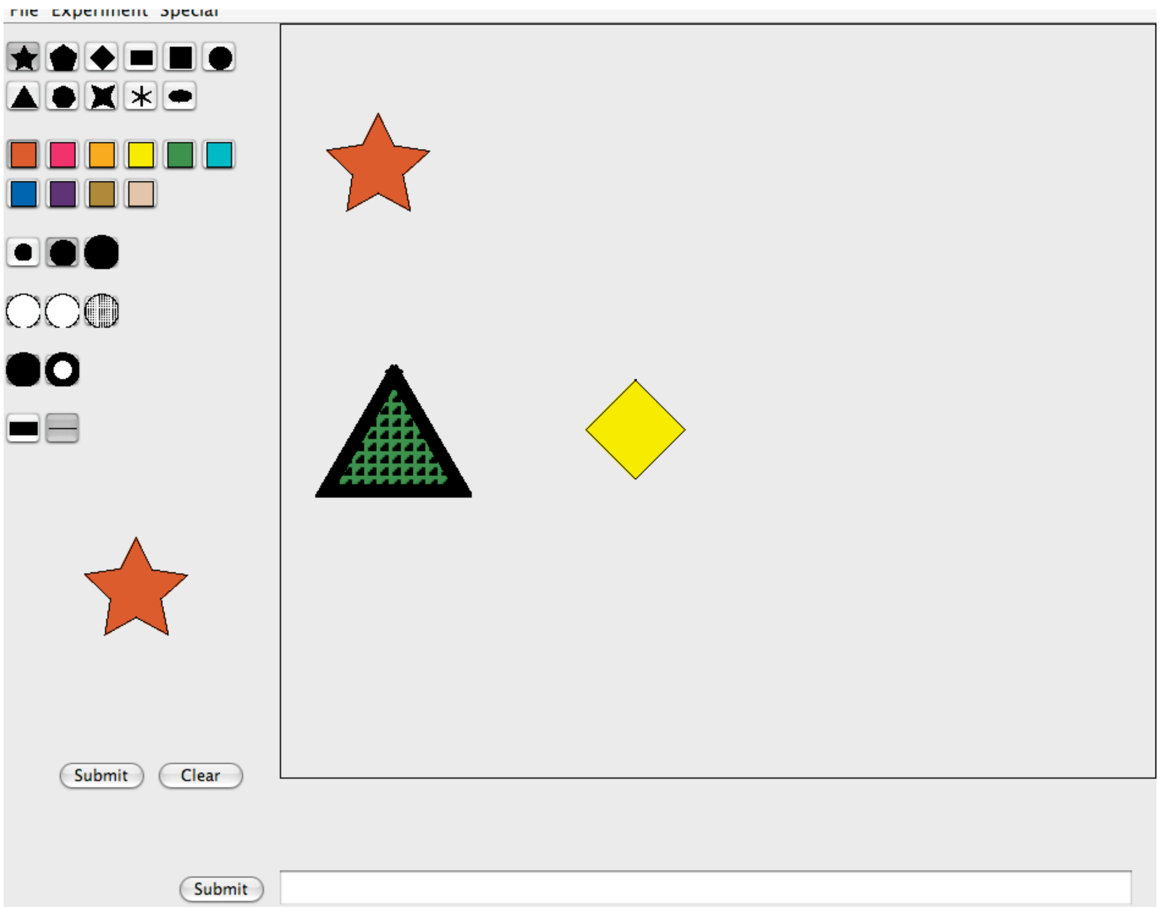

Figure 4. *A production trial with the target "red star solid green triangle dotted te yellow diamond left-of above" (*the solid, red star is above the dotted green triangle that is left of the yellow diamond).

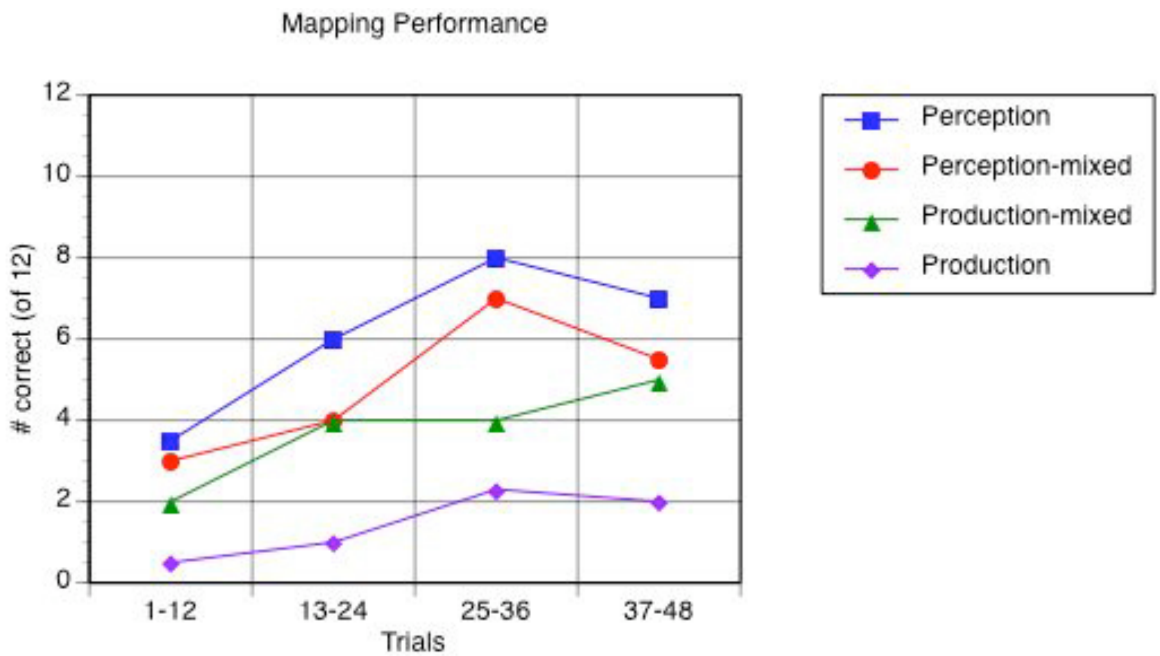

Figure 5.

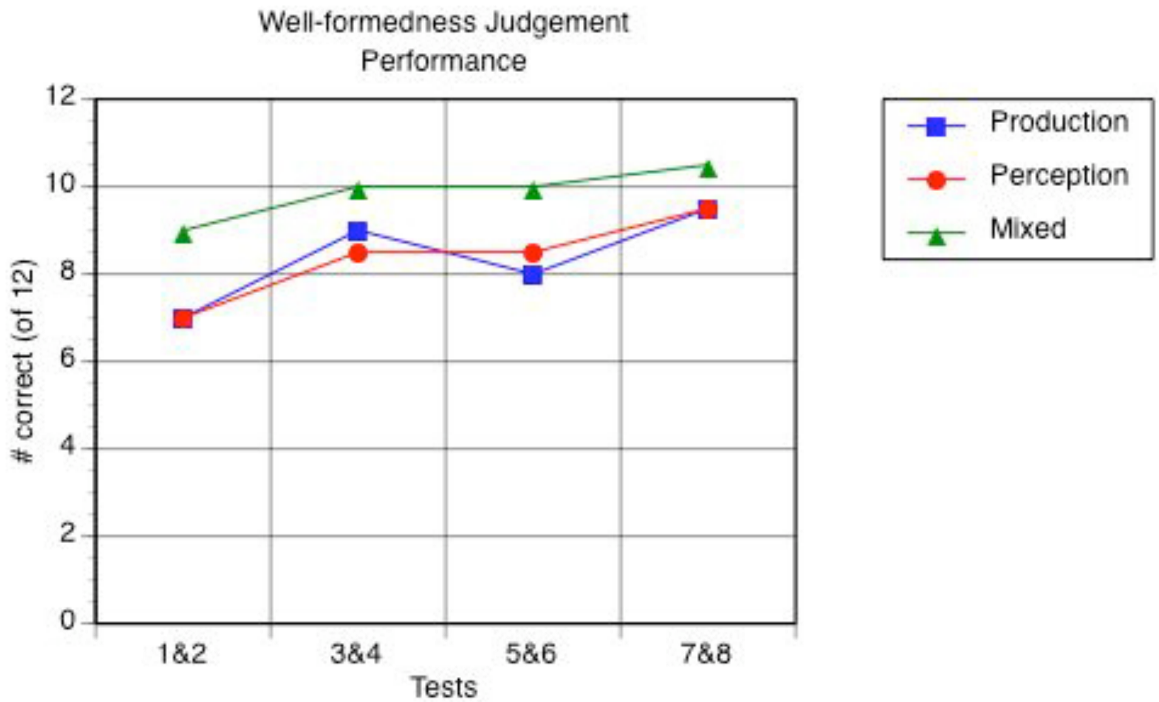

Figure 6

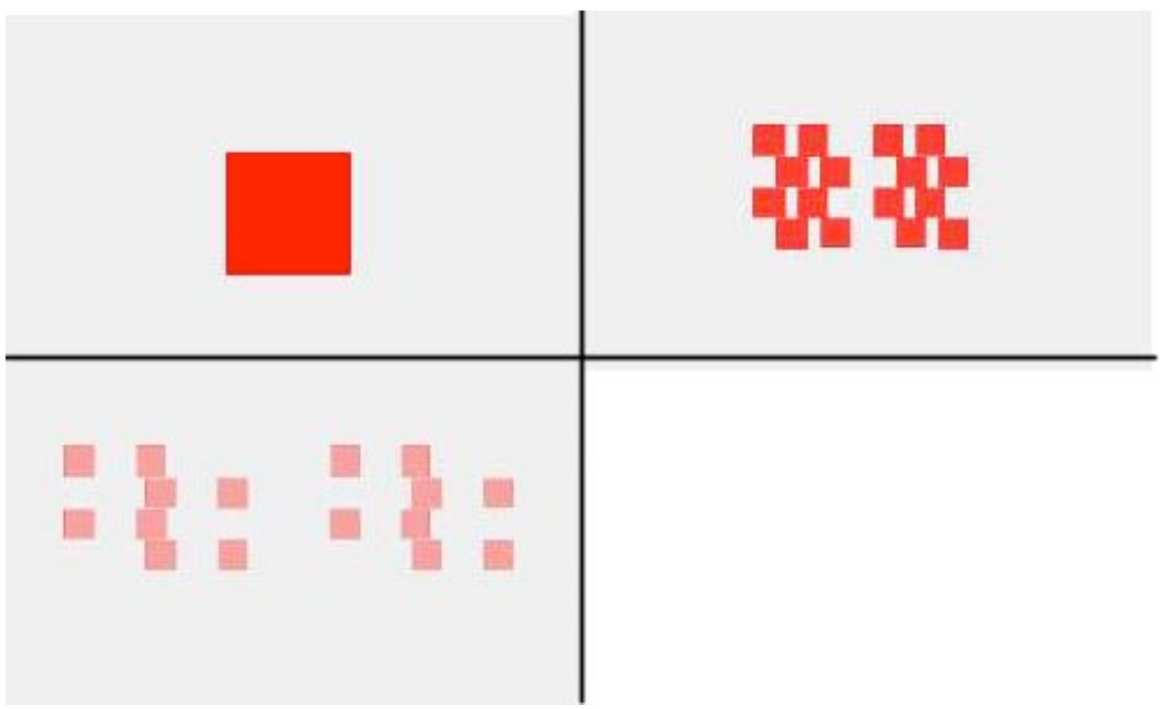

Figure 7. *A telic event ('explode') seen as a series of frames.*

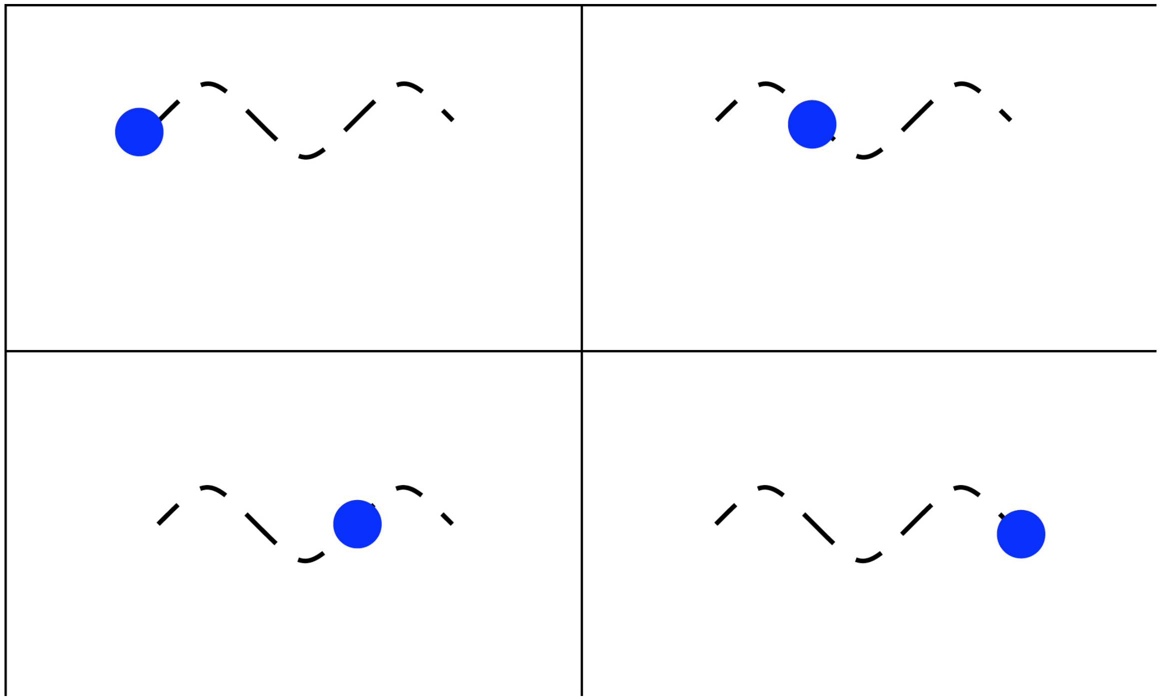

Figure 8. *An atelic event ('bounce') seen as a series of frames.*

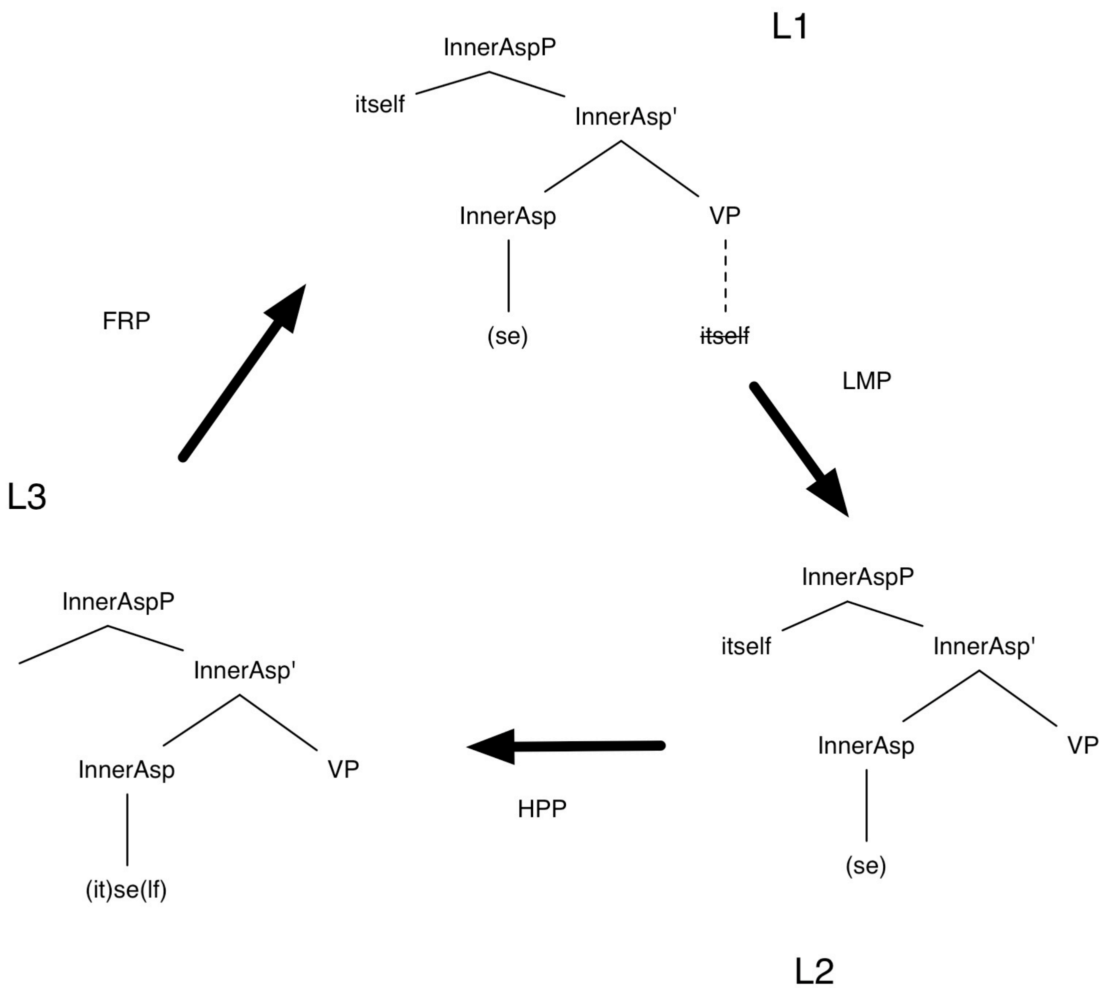

Figure 9. *A theoretically motivated telicity cycle.*

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