Symmetry in Visual and Linguistic Perception

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Like linguistic perception, visual perception is an active process in which the mind makes use of innate structural principles in the computational process. It is therefore useful to ask whether the visual and linguistic computational systems make use of the same or similar principles. This article describes the role played by principles of symmetry in visual perception as suggested by researchers in that field, and suggests that a subset of those principles play a strong role in the perception of linguistic structure. It is claimed that a distinction should be made between the construction of linguistic structure and its perception in the computational system, and that principles of symmetry apply in subtly different ways in each. It is argued that movement's inherent locality, successive-cyclicity, has a bipartite nature, being sensitive only to certain barrier nodes in the construction of structure while adjoining to every intermediate projection in the perception of structure.

Keywords: linguistic structure, successive-cyclic movement, symmetry, visual perception

[A]ny particular representation makes certain information explicit at the expense of information that is pushed into the background and may be quite hard to recover.

(Marr 1982: 21)

1. Introduction

A central insight of linguistic inquiry over the past half a century is that language interpretation is not a passive task, but an active one. Language, as it exists in the form of everyday speech, is understood to be a partially-specified phenomenon upon which the mind imposes additional requirements (hierarchical structure, for example). Much of linguistic inquiry is an effort to discover and better understand these requirements. Similar statements can be made about the cognitive understanding of visual perception. Visual perception is widely recognized as an active process wherein visual systems often compute fully-specified properties (such as motion or shape) given only partially-specified

This paper develops a presentation given at the Biolinguistics Investigations conference in Santo Domingo, Dominican Republic in February 2007. I thank the attendees for comments, especially Alberto de Almeida, Kamil Ud Deen, Charles Reiss, Karin Stromswold, and Ken Wexler. Thanks also to Cedric Boeckx, Michael Leyton, and three anonymous reviewers for very helpful discussion.

biolinguistics

ISSN 1450–3417

Biolinguistics 2.4: 291–316, 2008
http://www.biolinguistics.eu

stimuli. Just as in linguistics, there are therefore strong poverty of stimulus arguments for environment-independent, innate principles of visual perception.

Given these parallels, we might fruitfully ask the question whether some of these environment-independent principles in linguistic and visual perception might be the same. From both a biological and evolutionary perspective, to arrive at such a conclusion would not be surprising. After all, both language and vision are cognitive computational systems and are, with little doubt, the two that most dominate the human cognitive landscape: Humans are very visually and linguistically guided creatures. Furthermore, it is very likely that the human visual system predates by far our linguistic system in our evolutionary history. We suspect this because, physically speaking, other animals including apes and cats, have visual systems similar to our own (though with important differences), while of course no animal has a corresponding linguistic system akin to that of humans. This sequence of evolutionary development, therefore, makes the visual computation system a very likely source for the exaptation of computational principles that could be employed for linguistic computation as well.

In the present work, I suggest that this is the case: that a certain subset of computational principles employed by the human visual system in perception is also employed in the perception of linguistic structure. If this conclusion turns out to be correct, we will have uncovered some "third factor" principles in the sense of Chomsky (2005); that is, principles employed in linguistic computation that are not unique to language.

The principles I will consider here are principles of symmetry involving simple mathematical concepts from geometry and basic group theory. To find such principles playing a strong role in our cognitive processes is surprising;[1] nevertheless, that they play a role in visual perception is well-known, even if controversial and poorly understood. In this paper, I will suggest that they also play a role in the how we perceive and generate linguistic structure. I will specifically apply these principles to one linguistic phenomenon, successive-cyclic movement, that historically has been difficult to naturally implement in derivational theories of syntax. Briefly, successive-cyclic (SC) movement is the notion that overly long distance movement in syntax does not take place 'all-at-once,' but in a series of shorter, successive movements through intermediate positions. While there is a variety of empirical evidence that suggests S-C movement exists, syntactic theory has struggled for decades toward a natural implementation, often resorting to unmotivated ad hoc features to encode it. At the center of the difficulty has been disagreement about exactly which intermediate positions S-C movement targets: Some argue all available intermediate positions between the extraction site and final landing site must be targeted; others argue that it is only certain positions (barriers or phase edges, for example) that S-C movement is sensitive to. I will flesh out this history below and suggest that the role for principles of symmetry that I describe here is what is behind the lack of consensus. In doing so, I present an account that understands S-C

[1] Surprising even though, as a reviewer points out, the push toward greater simplicity and elegance are driving forces of the minimalist program. But as Chomsky as pointed out, if some strong version of minimalism turns out to be true, it is indeed surprising since one does not expect this of biological systems (Chomsky 2000: 9).

movement to have both a derivational and perceptual nature, each with its own properties. To provide a preview, my claim will be that, perceptually, S-C movement targets each available intermediate position while, derivationally, S-C movement targets only certain barrier-like projections (namely, [Spec,CP]). To the extent that the perceptual side of the account is true, I argue, most S-C movement needn't be explicitly encoded into the derivation of syntactic structures, thus eliminating the need for ad hoc features in the grammar.

This paper is organized as follows. In section 2 I outline the basic mathematical principles of symmetry that concern us. In section 3, I discuss a small subset of findings from the literature on vision that suggests these principles play an important role in visual perception. Then in section 4, I suggest that the same principles come into play in the perception of linguistic structure in similar ways. Indeed, I hope to show that this is a central finding of the linguistic enterprise over the past 50 years, though things are seldom discussed in these terms. Finally, in the second part of this section, I suggest that the principles discussed here offer an understanding of successive cyclicity that does not rely on unmotivated movement or current theories of phases. In tackling these issues, I hope to encourage others to think of linguistic theory in the terms employed here and to encourage the search for and refinement of general organizational principles that might be common to various human cognitive faculties.

2. Principles of Symmetry

The terms symmetry and asymmetry are used in various ways in various contexts, so it is important to define exactly what I mean by their use. When I speak of principles of symmetry here, I have in mind the meaning of the term as used by mathematicians. Unlike the common use of the term, the mathematic property of (a)symmetry is never inherent. That is, objects themselves cannot properly be said to be symmetric or asymmetric. Rather, the symmetry of an object can only be defined with regard to a *transformation* that relates the object to another image of itself. Transformations are simple, single step operations (such as rotation or reflection) that can relate two images. If the two images related by a transformation are identical, then that object is said to be symmetric under that particular transformation. For example, a simple square related to its image by a 90 degree rotation results in two squares that are exactly alike in every way. Thus, a square can be said to be *symmetric* under 90 degree rotation, or, to put it another way, a 90 degree rotation can be said to be a symmetry of a square.

The set of transformations under which an object is symmetric is said to be that object's *symmetry group.* This group will always be a closed set of transformations, since the combination of any two member transformations will always yield another member of the set. For instance, 90, 180, 270 and 360 degree rotations belong to the symmetry group for a square since the square is unchanged under any of those transformations. A vertical reflection transformation, which relates the square to its mirror image along a vertical axis, will also be a member. Combining this reflection transformation with, say, the reflection transformation with a 90 degree rotation, however, will yield nothing new since the resulting image will be exactly equivalent to a 180 degree rotation.

Given that a square is symmetric under so many transformations, we speak of it as having a high level of symmetry (though not as high as some other shapes, such as a circle). Now consider the relationship between the two images below. The image on the left is our highly symmetry square. The image on the right looks like a square that has had two triangular pieces cut from it. Unlike the square, the image on the right is not symmetric under a 90 or 270 degree rotation. Nor, unlike the square, is it symmetric under diagonal reflections along axes that bisect its right angles. Note, however, that the two images do still share quite a few symmetries: Both are symmetric under 180 degree rotations as well as vertical and horizontal reflections along axes that bisect their sides.

Figure 1: Symmetry breaking

Figure 1 thus illustrates the important concept of *symmetry breaking.* Some symmetries of the square on the left have been broken in the image on the right. Nevertheless, even when symmetry is broken, it is usually the case that a large amount of symmetry remains in common between related images. In fact, whenever two images are related via transformations, it will be the case that the symmetry group of the image with fewer symmetries will be a subset of the symmetry group of the image with more symmetries. It is this relationship between their respective symmetry groups that allows the two images to be related.

This basic understanding of symmetry preservation and symmetry breaking will be essential to the following discussion. Below, I will suggest that the mind makes use of the concepts of transformations, symmetry groups, and symmetry breaking when perceiving structural shape, and that these principles also form the basis for the construction and perception of linguistic structure.

3. Symmetry in Visual Perception

In any area of inquiry, scientists often find it helpful, in fact crucial, to take measures to tease apart the governing principles of a system from peculiarities of its performance in any particular application. Often this means removing a system from its typical functioning environment and seeing how it functions 'in a vacuum.' Linguists do this, for example, when they ask for grammaticality judgments on sentences without providing a discourse context. By doing so they sometimes find speakers have sharply negative judgments about a construction that they might otherwise accept in natural conversation. If one were to only examine natural corpora, one might never know about such judgments. The same kind of isolation and abstraction approach was taken regarding research in visual computation by the Gestalt school of psychology beginning over 100 years ago.[2] In undertaking this approach, researchers found that subjects had judgments about their visual experience that did not always line up with reality. To preview one case I will discuss below, one well-known effect the Gestalt school discovered was that objects can be perceived to undergo motion even though no actual motion has taken place, so-called 'apparent motion' effects.

In searching for possible explanations for these judgment phenomena, both vision researchers and linguists have adopted the very reasonable view that psychological experience in the absence of proper stimuli must be a reflection of the deep organizing principles of the mind, principles often obscured in usual cognitive performance. That is, vision and language perception are taken to be active rather than passive processes. In both cases, fully-specified experience is computed from only partially-specified stimuli, providing poverty of the stimulus arguments for innate principles of vision and language.

One of the most interesting insights into the nature of these basic organizing principles of vision is the central role that the above notion of symmetry seems to play. In this paper, I would like to focus on three general conclusions from the literature that illustrate this role. These are listed below:[3]

(1) a. Visual computation makes use of symmetry principles.
b. Where transformations are imposed by the cognitive system, it is the simplest possible transformations that are employed.
c. Symmetry principles are employed by the mind to infer past states of an object from the present one.

In the following subsections, I illustrate each of these conclusions in turn.

3.1. Computing Similarity

One subfield of visual computation is concerned with how judgments of similarity between objects are formed. The dominant view for the past twenty-

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2 A reviewer points out that the approaches taken to be analogous here are in practice somewhat different. Typically linguists study an object abstractly in order to determine its properties, only later and secondarily considering how the object might be integrated into its natural context. In vision, the typical approach is to study an object abstractly to determine its properties so that perception of the wider context in which the object is identified might be better understood. While the difference is significant, the basic methodology is similar enough to make my point: Studying natural objects in isolation reveals facts and generalizations not possible from looking at them in a natural context.

3 In the present discussion of visual perception, I am necessarily simplifying what are intense and complex discussions in a field I am only peripherally familiar with. While I believe that most researchers in the field agree that principles of symmetry and simplicity can be fruitfully applied to the kinds of phenomena I mention here, the precise role these principles play and what their origins might be are hotly debated topics. My purpose here is not to make a statement about what the conclusions of these debates should be. Rather, I wish only to draw attention to evidence that suggests that at some levels linguists and psychophysicists seem to be coming to similar conclusions about the workings of the mind, hopefully encouraging more discourse between these two important fields.

five years is the contrastive model of Tversky (1977) which takes similarity to be computed as a function of common and distinctive features of the objects that are being compared. In general, the more features two objects have in common, the more similar they are understood to be. But as Hahn & Chater (1997) have pointed out, the representations of natural objects cannot be fully specified by a list of features alone, but rather must also contain information about how such features are related to one another. It is therefore reasonable that object comparison would involve not just compiling lists of features to compare, but also consideration of relationships between corresponding features in the objects being compared

The view that such relationships are essential to computing similarity is taken up in Hahn *et al*. (2003) who develop a 'representational distortion' approach to similarity, arguing that similarity, rather than involving a comparison of relevant feature lists, is a function of transformational distance. Put simply, the simpler the transformational operations are that it takes to turn one object into another, the more similar the two objects are judged to be. I illustrate below with stimuli of the sort used by Hahn *et al*. in one of their experiments (based upon an experiment in Imai 1977) involving similarity judgments between sequences of black and white blobs that are transformationally related in various simplex and complex ways. In the table below, the pairs of representations are related either via one simple transformational operation, or a combination of two or three transformations.

No. of Trans.	Type	Stimuli: Item One	Stimuli: Item Two
1	Reversal	●○○○○○●●○●●● ●●●○●○●○●○●●	○●●●●●○○●○○○ ○○○●○●○●○●○○
1	Mirror	○●●●○○○●○●●○ ○○○●○○○●●○●●	○●●○●○○○●●●○ ●●○●●○○○●○○○
1	Phasic	●●○○●●○●○●○● ●●●●○○○○●●●●	●○○●●○●○●○●○ ○●●●●○○○○●●●
2	Reversal + Mirror	●○○○●○●○●○○● ●○○○●●○○●○●●	○●●○●○●○●●●○ ○○●○●●○○●●●○
2	Reversal + Phasic	●●○●●○●●○●●○ ○○○●○○○●○○○●	○●○○●○○●○○●○ ●○●●●○●●●○●●
3	Reversal + Phasic + Mirror	●○●○○●●●●○●● ○●●○○○●○●●○●	○●○○○○●●○●○○ ●○○●○●●●○○●○

Table 1: Sample stimuli used in Experiment 1 of Hahn *et al.* (2003)

Hahn *et al*. tested such pairs of stimuli (which also included deletion and insertion as basic transformational operations in addition to reversal, mirror, and phasic operations) with psychology students and found an almost linear relationship between the number of transformational required to relate two items and how similar they were judged to be. On a scale of one to seven, subjects assigned pairs of items related by a single transformation an approximate score of 5 while those related by two transformations were assigned an approximate score of 4. Those related by three transformations received a score of approximately 3.5 while controls (which could not be related by three or fewer transformations) were around 2.5. Thus, the major finding of Hahn *et al*. is that a strong correlation exists between similarity judgments and the number of transformations relating a pair of stimuli: The more transformations involved in relating one object to its counterpart, the less similar the stimuli are judged to be.

Hahn *et al*.'s experiments provide strong evidence that principles of symmetry are central to the cognitive computation of similarity.[4] But how does Hahn *et al*.'s approach to these results compare with a feature-based account? The question is not so easy to answer since one of the well-known problems (or strengths, depending upon one's perspective) of feature-based approaches is that exactly what constitutes a relevant feature is only defined for particular contexts. In the present case, however, Hahn *et al*. show that a feature-based approach can only fare as well as their own if, trivially, the features that are assumed to be relevant are the shape properties of the items that remain unchanged under the applied transformations; in other words, only if the symmetries of the objects are counted as features. This strongly suggests that how similar two shapes are judged to be is a function of the number of symmetries preserved by the transformational relations that relate them. The conclusion is that symmetry is a central organizing principle in similarity judgments.[5]

3.2. Symmetry and Apparent Motion

The second domain of inquiry in visual computation to be discussed here has to do with what is known in the literature as apparent motion, a phenomenon first described by Wertheimer, Kroffka and other Gestalt psychologists (e.g. Koffka 1935, Wertheimer 1912). In modern work, the name most associated with the psychophysics of apparent motion is Roger Shepard, whose work on the topic is both highly admired and highly controversial. In apparent motion experiments, two images are flashed on a screen in different positions and in close temporal sequence. Typically, subjects report experiencing the object moving across the screen from one position to the other, even though no motion actually took place. This alone points to the active nature of the perceptual process. As Shepard notes, "Quite apart from questions about the particular type of movement experienced, the fact that any connecting movement is experienced is presumably the manifestation of an internalized principle of object conservation" (Shepard 2001: 582). That is, Shepard views apparent motion as resulting from the implicit assumption that two objects viewed in close temporal and spatial proximity are assumed to be the same object, even if they appear in different locations and with slightly different shapes. Apparent motion is a solution to the spatial disparity between the two objects while transformational operations are employed to relate any shape or orientation disparities. In other words, Shepard is arguing that

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4 See also Kemp *et al*. (2005) for a 'generative' theory of similarity that encompasses and expands the transformational approach. Briefly, Kemp *et al*. argue that two objects are judged to be similar to the extent that they are judged to be formed by the same process.

5 For a strong view of the role transformations may play in perceptual processes, see Foster's (2001) commentary on Shepard (1994/2001).

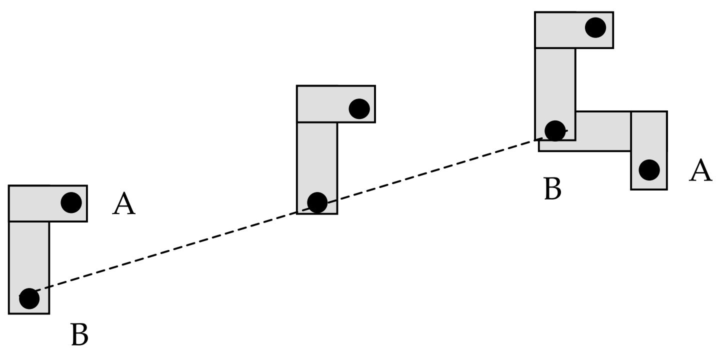
internal principles of symmetry and transformation play an important role in visual perception.

Perhaps even more interesting than the fact that apparent motion exists and employs principles of symmetry, however, are the details of exactly what sorts of transformations the mind prefers to impose in apparent motion experiences. In simple cases where the only difference between the two objects is its position in the visual field, the facts are not very interesting: Subjects experience direct, rectilinear translational motion between the objects' positions (that is, movement in a straight line). More interesting cases involve differences not just in the position of the object, but also orientation. Take, for instance, the objects in Figure 3. In order to see these objects as being the same object in an apparent motion experiments, subjects must not only relate them spatially, but must also perceive a clockwise rotation of 90 degrees (illustration taken from Todorovič 2001).

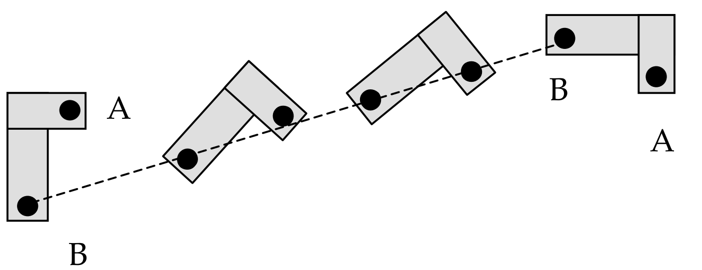
Figure 2: In apparent motion experiments, subjects experience movement between one position/orientation and another, even though movement has not really taken place

Obviously the two transformations that relate the object on the left to the one on the right are translation (movement) and rotation (orientation), but one can imagine a number of different combinations of these transformations that subjects might experience. One possibility is a sequence of translations followed by a single 90 degree rotation. This is option (a) in Figure 4 below. Another is a sequence of combinations of translation/rotation transformations in which the object rotates a little with each movement along a straight path from A to B, shown in option (b). However, typically subjects experience neither of these. Rather, they report experiencing the motion in option (c).

(a)



(b)



(c)

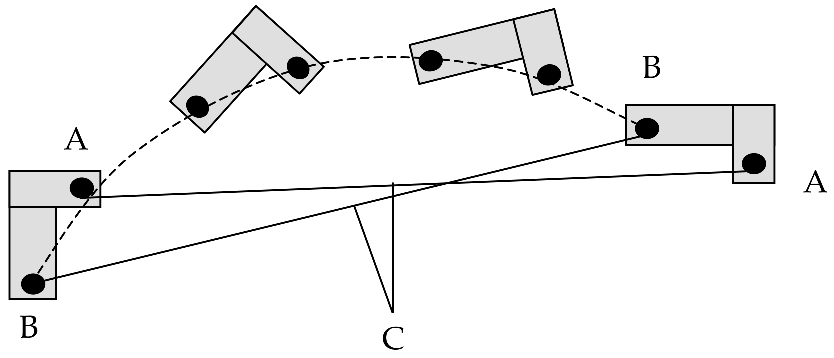


Figure 3: Possible transformation sequences relating object in first to object in second position (in an apparent motion experiment, (c) is most commonly experienced motion)

The motion in (4c) can be described in two ways: One is a sequence of translation/rotation combinations (like the option in (4b)) that just happens to follow an arced path. Another, simpler way is as a transformation of *pure rotation* that involves no translation at all. This rotation takes place around a point C which can be found by the intersection of perpendicular bisectors of the distance between A and B.[6] Discussing this finding, Shepard (1984) argues that the preference is based on economy concerns; he argues that in visual perception the cognitive faculties have a strong preference for employing a unique, simplex transformation (those that involve a single transformational operation) over complex transformations (those that involve a combination of such operations). This conclusion is particularly striking in the present case since the preference for a simplex transformation makes the overall computation more complicated (from one perspective, at least) since it requires computing point C.

I hasten to note that Shepard's conclusions are not uncontroversial and are in fact hotly debated. [7] However, his conclusion from apparent motion studies builds on the conclusion from Hahn *et al.*'s similarity experiments: Not only are principles of symmetry relevant for visual computation, but the computational system shows a preference for the simplest possible transformational sequences.[8] In the area of visual perception at least, this evidence suggests that cognitive judgments about similarity and object conservation are based on the simplest application of symmetry transformations.

3.3. Symmetry and Shape History

The third conclusion I would like to discuss here is concerned with how judgments are made about the past states of an object, or its shape history. That

[6] Note that, if one described this motion in the first manner mentioned, one would still need to compute point C, but there would be no explanation for why the translation/rotation is experienced along an arc rather than in a straight line. For this reason, pure rotation must be the preferred interpretation of the facts.

[7] See volume 24 of *Behavioral and Brain Sciences* for a reprinting of Shepard's important 1994 paper (= Shepard 2001), and a variety of papers and comments reacting to it as well as the interesting research it has encouraged.

[8] See Todorovič (2001) for arguments that determining what is meant by 'simplicity' in these cases is not in itself a simple matter.

is, given the present shape of an object, what do we infer about its previous states and how do we infer it? In a way, this topic is closely related to the topic of similarity judgments except in the present case one is extrapolating from a presently observed object what its similar, past state must have been. If we are right in following Hahn *et al*. (2003) in supposing that principles of symmetry play a central role in similarity judgments, we should not be surprised to find them operating in the domain of object shape history as well. Indeed, Leyton (1992) asserts that this is the case, arguing that when we observe an object with a low level of symmetry, we automatically infer that in the past the object must have had a higher level of symmetry. Leyton suggests that one common experience illustrating these principles is the observation of a dented can. Observing the shape asymmetries of the can, we infer that at some point in the past the can did not have a dent and that its shape was symmetric in the relevant ways. Moreover, we commonly assume that the can obtained its dent from a single causal event that introduced a symmetry-breaking transformation – a fall from a shelf, for instance.

Leyton (1992) reports on experiments he conducted in the 1980s which suggest the psychological reality of this symmetry-inferring process. Subjects in one experiment were provided only with a rotated parallelogram. Asked to construct a previous state for parallelogram, subjects typically constructed a non-rotated parallelogram. When subjects were then asked to construction a previous state for this shape, a rectangle was typically produced. Finally, asked to construct a previous state for the rectangle, subjects constructed a square. The entire sequence is seen in (6). Note that what subjects have done here is apply simplex transformations, one at a time, in such a way as to gradually increase the symmetry group of the object and restore maximal symmetry to the shape, taking it from a rotated parallelogram, which is symmetric under very few transformations, to a square which is symmetric under many more transformations in a step-by-step fashion.[9]

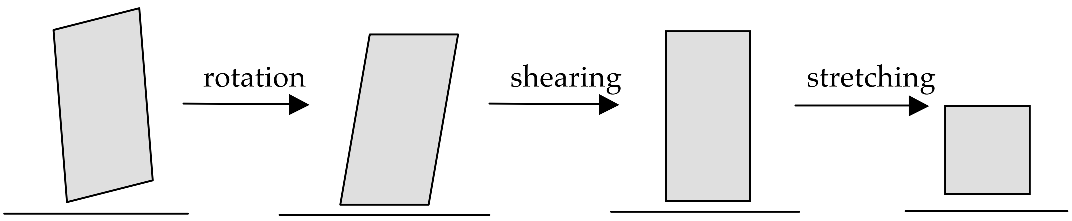


Figure 4: Leyton's subjects inferred the rotated parallelogram's shape history by applying simplex transformations one at a time to create progressively more symmetric shapes

The general conclusion Leyton draws from these results is that, psychologically, present asymmetries in the shape of an object are understood as having resulted from past symmetries.[10] Part of visual computation involves computing a

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9 As a reviewer points out, the rotated and non-rotated parallelograms in Figure 4 only have different symmetry groups with respect to the horizontal line below them. This line was included in the original study.

10 Leyton applies his conclusions to domains outside the realm of visual computation alone, even showing how these principles apply to Transformational Grammar.

sequence of past states for an object, each with a symmetry group larger than the one it precedes. Furthermore, as in the case of apparent motion, these states are related by simplex transformations where possible: Rather than seeing a rotated parallelogram as resulting from a single past state (the square) that underwent a single complex transformation composed of stretching, shearing and rotation in Figure 6, subjects instead infer three previous states for the object, each related to its predecessor by a single simplex transformation. This is further confirmation of the conclusions drawn in the previous two sections, that human cognition makes use of principles of symmetry with special preference given to simplex transformations over complex ones.

Finally, another important (though on the surface, trivial) conclusion here is that while present asymmetries are taken to result from past symmetries, present symmetries are assumed to always have existed and no differing past state is taken to have existed for them. Again, the dented can serves as an example: If someone dents the can and then flawlessly repairs it, an observer will infer that the can has always existed in this state. Previous states in which an object has a smaller symmetry group (is more asymmetric) than its present state are never inferred.

3.4. Conclusions

In the previous three sections I have introduced three ways in which principles of symmetry under transformation have been found to be important for visual psychology and computation. I summarize them here. First, these principles explain some judgments of similarity which are difficult to account for using feature-based models. Second, when there is a choice in relating images, single-step transformations are preferred over multi-step transformations, even if this might result in a more complicated computational load as in the case of apparent motion. Third, part of computing the present state of an object involves computing its past states which are always computed as being more symmetric than the present ones: Past symmetry is inferred from present asymmetry. Present symmetry, on the other hand, is assumed to be present in all past states of the object.

4. The Perception of Linguistic Structure

Given that the three conclusions described above are relevant for the computation and perception of the structure of visual objects, we might ask whether similar principles and conclusions are also relevant for the psychological perception of linguistic structure. In this section, I argue that this is the case and that, in fact, linguists already implicitly recognize the centrality of these principles. As I will show, many of the basic ideas of our theories about syntactic structure have been based on principles of symmetry, though things have seldom been discussed in the present terms. Finally, I will argue that being more explicit about the role being played by symmetry principles suggests a solution to an enduring problem for syntactic theories, namely successive-cyclic movement.

4.1. *Symmetry in Linguistic Theory*

To apply the principles we have been discussing, we must start with some basic questions and answers. Unlike in visual perception where the variety of forms that must be processed is wide-ranging and nebulous, linguistic structure is well-defined and variation is highly constrained. Therefore, we do not expect the full range of principles active in visual perception to be active or required in linguistic perception. Rather, we might at most expect to find a subset of those principles whose functions are compatible with the requirements of linguistic structure.

To begin, we must ask what the basic shape of linguistic structure is and what the relevant transformations that preserve/break its symmetry are. Though not typically stated in these terms, mainstream generative syntactic theory can be thought of as a central state whose symmetry is broken under two general simplex transformations. I take this central symmetric state to be the basic system of a predicate and its arguments commonly refer to as argument structure.[11] The two transformations that, when applied, break the symmetry of this state, are projection and movement, which I take to be linguistic terms for the simplex transformations dilation and translation (more on this below). The application of these transformations to argument structure introduces asymmetries that obscure the core symmetries of the latter. [12] Projection, for instance, introduces functional structure that may be irrelevant for the interpretation of argument relations while movement often makes selection relationships obscure for the listener. Given a full-fledged linguistic structure to which projection and movement have applied, then, the task for linguistic perception is to reconstruct the past symmetric state of argument structure from the present less symmetric state created by projection

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11 By 'argument structure' I refer to a verb and its internal arguments, taking subjects to be an argument of a functional level of structure projected above the lexical VP level. I further assume that if a verb has more than one internal argument, they are each related to the verb via symmetric complement relations. Given standard tree representations, this requires that ternary branching be permitted at least at the lexical level. I put aside the wider implications of this assumption since they are not central to the theme of this paper.

12 Another relevant debate in linguistic theory can also be stated in these terms, namely the debate about whether headedness is a property of syntax or not; in present terms, whether binary branching linguistic structure is symmetric under the reflection transformation. Much work beginning with Kayne (1994) has argued that it is not, imposing uniform right-branching structures on all languages. Others have maintained that it is symmetric under reflection and that whether a language has right or left branching structure is a matter of parametric variation. A synthesis of the two approaches is presented by Moro (2000) who argues that anti-symmetry is imposed by the interface with the phonological component. In the same spirit of the present work, Moro refers to reflectively symmetry binary structures as 'points of symmetry' that must be broken, made anti-symmetric, in order to be linearized (and thus pronounced). He argues that movement occurs as a function of spell-out to break these points of symmetry. Moro's view conflicts with the present account in which movement is taken to be motivated by morphological (feature checking) considerations. Whether the two could be compatible is an interesting question that would seem to hinge on whether or not Moro's approach to movement can derive a uniform paths approach to successive-cyclicity, the chief fact that I argue the present account enlightens.

and movement.[13]

Though projection and movement are symmetry breaking operations for argument structure, the resulting structure still maintains a large amount of symmetry, in particular its binary-branching and hierarchical structure. Since these two structural properties are not disrupted by projection or movement (only one level of functional structure at a time can be projected at any given step in a derivation, and movement does not result in structure being destroyed), they are symmetries of the system. Furthermore, it is the maintenance of these symmetries that allow a full-fledged linguistic structure to be related to its core argument structure as the latter's highly symmetric state is inferred from the former's less symmetric state, much as the two shapes in Figure 1 above or in Leyton's dented can thought experiment. The mind infers the past symmetric state of argument structure from the present asymmetric state of a full functional structure.

The idea that argument structure is the core symmetry of linguistic structure was explicitly encoded in Chomsky's (1981) Projection Principle which (among other things) imposes that the requirements of argument structure be projected into the syntax and represented at every level of syntactic structure. To state things in the present terms, the Projection Principle ensures that the past-state, central symmetry of syntax (argument structure) will always be recoverable from the output (present state) of a syntactic derivation. In other words, the Projection Principle simply formalizes the task for linguistic perception as it is understood here: Recovery of past symmetry from present asymmetry.

The particular past states of the syntactic object are also encoded in our present theories within the formalizations of the two basic transformations employed by syntax: movement and projection. For movement, this is encoded explicitly in the system of copies or traces that relate the surface position of an object to its original position (the latter dictated by argument structure). For projection, things are less explicit, but formalizations can be found in the idea of the extended projection (Grimshaw 1991) or the morphological word (Brody 2000), both encoding the idea that functional structure is a projection of its lexical base. Even in systems in which functional heads are not formally related to their lexical counterparts (such as those employing Merge as a basic structure-building operation), the history of projection is encoded in the hierarchical order of functional and lexical projection in the syntactic tree: those lower in the tree and thus closer to the lexical projection are projected earlier than those higher in the tree. The most explicit encoding in the Merge systems is in the so-called 'cartographic' approach which takes the number and ordering of functional heads in the hierarchical structure to be universal (e.g. Cinque 2002, Belletti 2004).

Regardless of the precise formalization, what is important here is that modern theories of syntax have formal ways of encoding the reconstruction of the past symmetric state (argument structure) from the present asymmetries

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[13] By the 'perception' of linguistic structure, I am referring to the process by which LF representations are interpreted by the conceptual-intensional system. As I attempt to show below, my intention is not to supplant the LF representations of any particular theory, but rather to illustrate that the technology employed in such representations of the Chomskyan tradition encodes the fact that the reconstruction of past symmetries I discuss here is a primary function of interpretation at LF.

imposed by the syntactic transformations of movement and projection. It is thus an insight of linguistic theory that the principles being discussed here are crucial for the human linguistic system.

Within this line of thinking, it is useful to consider exactly what kinds of transformations projection and movement represent and how, specifically, past states must be inferred from them. Projection, as it is commonly understood, iteratively expands the structural space of the core symmetry of argument structure. Functionally, this is identical to the geometric transformation of dilation, a transformation that relates an image to an identical image that is proportionally larger or smaller.[14] A good example is a system of concentric circles. Each circle is related to the next smallest or largest circle by dilation. A system of such circles is reduced to its smallest member by beginning with the outermost circle and iteratively applying dilation, removing one outer circle at a time until only the smallest, most central circle remains. Projection is the same. Given an object to which projection has applied, past states of the object must be inferred by removing these dilational expansions one-by-one. To illustrate using conventional tree structures, the leftmost tree in Figure 7 would be inferred to have the previous states to its right. Here H0 is understood as a lexical element while H1 and H2 are functional heads projected from it.

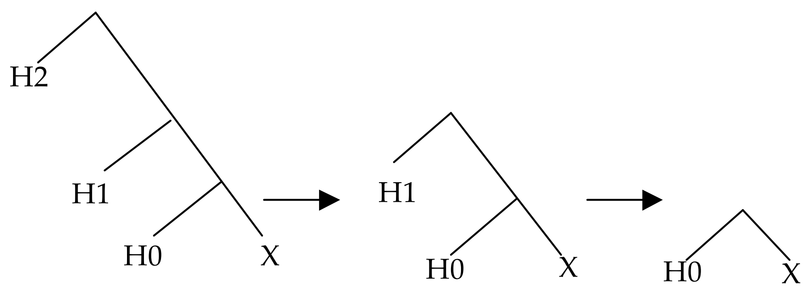

Figure 5: Removing functional projection to restore symmetries of argument structure

The movement transformation, on the other hand, involves displacing a lexical element. This is directly analogous to the geometric transformation of translation, discussed in section 2 above. Inferring a past state to which movement has applied therefore involves reconstructing a moved element to its original position. This is illustrated in Figure 6 and is in fact commonly referred to in the linguistic literature as 'reconstruction'.[15,16]

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14 The analogy of dilation was explicitly discussed by Cedric Boeckx in an earlier 2004 version of what became Boeckx (2008). The discussion of dilation is absent from the latter work, though the basic idea of projection as an iterative expansion of functional structure projected directly from the lexical item remains.

15 Reconstruction may be implemented in many ways. A reviewer asks how the perceptual reconstruction discussed here compares to the understanding of reconstruction associated with the copy theory of movement. On the view developed here, however, the fact that a moved element leaves a copy of itself in its original position is simply an implementation of the fact that linguistic perception requires reconstructing moved elements to their positions of origin. A system based in trace theory would work just as well for my purposes.

16 As a reviewer points out, these two transformations differ in the groups they belong to.

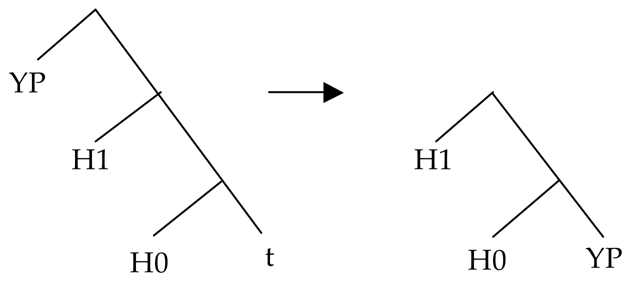

Figure 6: Reconstructing a moved element

Finally, it is also important to note that in most of the literature projection and movement do not apply randomly and without cause. Rather, they occur as the results of distinct causal relationships built into the theory. The concept of causation also has a central role in the discussion of shape history in Leyton (1992). Leyton postulates that present asymmetries are not only used to infer a past symmetric state, but are also assumed by the mind to be the result of an outside causal entity acting upon that state. Not only do we infer the undented can from the dented one, but we also infer that there must have been some outside agent that caused the dent. Interestingly, this principle of causality is also encoded in present syntactic theories in systems of feature checking and (some version of) Full Interpretation (Chomsky 1986). Features are outside causal entities that induce transformations.[17] Functional features induce the projection transformation in order to create representational space for their expression. Movement-related features (EPP features, 'strong' features, criterial features, etc., depending upon the framework), on the other hand, induce the movement transformation in order to satisfy the morphological and/or syntactic requirements of a language (in many systems, by in some sense 'checking' the features that projection has created space for). These two kinds of features (or at least two kinds of ways of talking about them) encode the fact that projection and movement are distinct types of transformations with distinct purposes in the computational system (creating representational space and fulfilling morphological requirements, respectively). Since the two have distinct causes, the present view suggests that collapsing projection and movement into one general transformation as some have proposed (Starke 2001, Boeckx 2008, among others) might be misguided (though certainly not ruled out in principle).[18]

Since it only affects the property of size, images related by dilation do not differ in their symmetry groups while images related by translation often do. Therefore, removing layers of projection as in Figure 5 does not by itself increase the symmetry group of the structure (though I will suggest in section 4.3 that, indirectly, it does).

17 A reviewer points out that features are methodological tools of a theory rather than empirically observable facts and so are unlike real-world causes of real-world asymmetries. However, the commonality pointed to here is that in both kinds of perception there is an innate assumption that present asymmetries are brought about by outside causal entities. Thus the reason we assume someone dented the can is the same reason we assume features. Whether or not features are the best methodological tool to encode this is a separate question I will not deal with.

18 Again, I refer the reader to Moro (2000) for a different view of movement-as-symmetry-breaking that is not based upon a feature-based theory of movement. Note, however, that

Crucially, however, while I am claiming projection and movement should be considered distinct and independent operations in the imposition of asymmetries on linguistic structure, this says nothing about the process by which those asymmetries are removed from the system when linguistic structure is perceived. That is, we must differentiate between the production side of the linguistic computational system and its perception side.[19] The distinction is motivated by the primary requirements of these two sub-systems: While the production sub-system is chiefly concerned with satisfying well-formedness requirements (checking features, satisfying Full Interpretation, etc.), the perception sub-system is chiefly concerned with reconstructing the past symmetric states of system in the most economic way possible. Thus, while we expect both sub-systems to make use of the same basic principles in producing and perceiving linguistic structure, they may apply them in subtly different ways, specifically when the perception system is able to remove asymmetries in a way that is more economic than the production system was able to impose them. I return to this point below.

To recap the present section, projection (dilation) and movement (translation) are simplex transformations that apply to the symmetric state of argument structure (typically iteratively). The task for linguistic perception is to reconstruction the past symmetric states of the derivation given the asymmetries that projection and movement have imposed upon it. Note that, given the discussion in section 3 above, we expect that the particular past states inferred for a present state should be related via single simplex transformations where possible. In the next section, I attempt to show that this prediction yields important results for our understanding of successive-cyclic movement.

4.2. Successive-Cyclic Movement and Its Discontents

Successive-cyclic movement is the simple idea that movement in syntax that is sufficiently long-distance does not take place in one fell-swoop, but requires a successive series of shorter movements. Though originally proposed as a solution to a theoretical problem in Chomsky (1973), a variety of empirical evidence from every sub-discipline of linguistics has since converged on the idea that some version of S-C movement exists. To present just two examples of semantic evidence for S-C movement, consider the following data from Fox (2000), an instance of topicalization.

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even in Moro's approach, movement and projection have distinct causes, with movement caused by linearization and projection caused by feature requirements.

19 To reiterate fn 13, by 'perception,' I refer to a (sub-part of) interpretation that is a part of the linguistic computational system and not an active, online perceptual process. I stand agnostic about how these perceptive principles interact with models of language processing, though it is possible, as a reviewer suggests, that just as apparent motion is an effect brought about by the processing of certain visual stimuli, the sorts of effects I examine here could be taken as the results of processing certain linguistic stimuli, or of more general aspects of processing such as its top-down nature.

(2) [The papers that he$_i$ wrote for Ms. Brown$_j$], every student$_i$ asked her$_j$ to grade ___.

(2) is interesting since standard binding consideration prevent the moved NP from being interpreted in either its surface position or its original position. Variable binding requires that *he* be c-commanded by the quantifier phrase *every student* in order to yield the proper interpretation, while Condition C of the binding theory requires that the R-expression *Ms. Brown* not be c-commanded by the coreferential pronoun *her*. In (2) the only place the NP can be interpreted to satisfy both conditions is in an intermediate position somewhere between *every student* and *her*. Of course, in order to be interpreted in this position, the constituent must have moved through it in the course of its movement from its original position to its surface position, thus providing evidence for S-C.

Another widely-known piece of semantic evidence for S-C goes back to Barss (1986) and concerns anaphor interpretation. According to Condition A of the binding theory, anaphors must be bound by a local antecedent. In (3a), for instance, *himself* can only refer to Bill and not John. In (3b), however, the NP containing *himself* has undergone movement. Note that here both interpretations are possible.

(3) a. John$_i$ thinks that Bill$_j$ hates the picture of himself$_{*i/j}$.
b. [the picture of himself$_{i/j}$] that John$_i$ thinks that Bill$_j$ hates ___.

While the coindexation with *Bill* follows from the NP being interpreted in its base position, coindexation with *John* is only possible if the NP containing *himself* enters a local binding relation with *John* in the course of the derivation. In other words, the NP must pass through an intermediate position somewhere below *John*, but above *Bill* in (3b), another argument for S-C.

While the phenomenon of S-C movement is well-established, its exact nature continues to be a subject of great debate. At the core of the discussion are two questions, one empirical and one theoretical. The empirical question is, precisely what intermediate positions does movement target? As both Abels (2003) and Boeckx (2007) have discussed, there are two general options available. Either S-C movement targets particular positions (what Abels calls the *punctuated paths* possibility) or S-C movement targets every possible position between its first and final landing sites (Abels' *uniform paths* possibility). While a number of recent proposals have come down in favor of a uniform approach (Fox 2000, Richards 2002, and Bošković 2002, 2007, among others; see Boeckx 2007 for an overview), the majority of the work on S-C movement has assumed a punctuated path approach. These works assume that certain nodes are bounding nodes (or barriers or phase level categories, depending upon the specific system assumed) that are barriers to movement. In order for movement to be considered legitimate by the computation system, it must proceed through the specifier positions of the barrier nodes. A version of each of these systems is illustrated below using the sentence *What did Mary think John bought?* (4a) represents a (version of a) punctuated understanding of S-C wherein the XP moves through only intermediate [Spec,CP]'s on its way to is final landing site. (4b) represents the same structure in a uniform path framework. Here the XP is adjoined to every projection between its original and final positions.

(4) a. [$_{CP}$ ***what did*** [$_{TP}$ ***Mary*** <*did*> [$_{VP}$ <*Mary*> ***think*** [$_{CP}$ <*what*> C [$_{TP}$ ***John*** T [$_{VP}$ <*John*> [$_{V'}$ ***bought*** <*what*>]]]]]]]

b. [$_{CP}$ ***what did*** [$_{TP}$ <*what*> [$_{TP}$ ***Mary*** <*did*> [$_{VP}$ <*what*> [$_{VP}$ <*Mary*> ***think*** [$_{CP}$ <*what*> C [$_{TP}$ <*what*> [$_{TP}$ ***John*** T [$_{VP}$ <*what*> [$_{VP}$ <*John*> [$_{V'}$ ***bought*** <*what*>]]]]]]]]]]]

The central empirical question, then, is whether (4a) or (4b) is a more accurate description of the derivation of such sentences. I suggest that in fact both are accurate, in a way to be made clear below.

Another concern in the decision between the uniform and punctuated paths approaches, however, is more conceptual in nature. Namely, if one adopts a punctuated path view, then why does S-C movement target some nodes and not others? While there have been many systems proposed for deriving a punctuated system of S-C movement, none of them has achieved the sort of natural implementation that the minimalist program seeks from a theory. No natural system of bounding nodes or barriers was ever achieved, and in the current phase system of Chomsky (2001, 2008) there does not seem to be a natural connection between available EPP positions and phase category, even if the latter are taken to be natural propositional chunks of structure (see Boeckx & Grohmann 2007 for an overall critique of the phase system). The punctuated approach to S-C movement, then, has proven extremely difficult to motivate and implement theoretically. The uniform approach, however, does not suffer from this problem since it takes S-C movement to simply be a property of movement itself: Movement must be local, targeting every projection between its first and last position. There is no need to single out particular projections as special with regard to movement.

Even under the uniform approach, however, a conceptual question arises: If movement really is so local, why is it so local? Bošković (2007) and Boeckx (2007) contend that movement essentially comes for free as a derivational option that the grammar allows in order to allow syntactic objects to check their uninterpretable features as efficiently as possible. As long as some element has an unchecked feature, it continues to move up the tree (merging with each project in Boeckx's case) until all of the heads required for it to check all of its features have been introduced. Then movement stops in that position. Going further, Boeckx (2008) suggests that movement appears to target every projection due to the fact that, though typically formalized separately, movement and projection are really one and the same operation. An element moves from its initial position to its final landing site not separately from the projection operations that articulate the sentence's structure, but along with this projection. As each level of projection is iteratively added to the structure, movement 'piggybacks' onto it, in this way percolating up through the clause until its final landing site is reached.

While these approaches certainly provide us with a natural way of thinking about S-C movement, it is not clear that they are the best at capturing the facts typically taken as clear evidence for S-C. Furthermore, the idea that movement comes 'for free' with projection only seems natural to me if movement and projection are indeed fully collapsed to a single operation as Boeckx (2008) argued. Yet, as discussed above, projection and movement are unique transformations (dilation vs. translation) and, more importantly, have unique causal origins. Therefore, I do not believe collapsing them to a single operation is the best approach. Despite this, however, I do believe that a partial conflation is possible if we take seriously the idea that the derivation of a structure may employ principles in subtly different ways than the perception of the same structure as suggested above. I expand on this below.

4.3. Uniform Successive Cyclicity as a Perceptual Phenomena

Recall the conclusions drawn from the field of visual perception discussed above. There I suggested that cognitive judgments involve using the simplest possible principles of symmetry to reconstruction past states of a present object with perceived asymmetries. I have also suggested, however, that the simplex transformations that are inferred to relate a present state to a (more symmetric) past state may be different from the transformational operations that caused the relevant present state to come into being in the first place. In particular, though multiple complex transformations may change a highly symmetric state to a less symmetric one, the cognitive faculty will, given only the present state, infer the change to have resulted from single, simplex transformations when possible, as in cases of apparent motion perception. Thus there may be differences between the temporal construction of an asymmetric state on the one hand and the inference of its past symmetric state on the other: While both are constrained by general concerns of economy and simplicity, those concerns may be manifested in different ways depending upon the particular requirements of the system.

I would like to suggest that this difference is relevant for the derivation/construction and perception/inference of linguistic structure as well. In particular, I am suggesting that while in the derivation of linguistic structure asymmetries are introduced by two distinct transformations with distinct causal relations (projection and movement), in the perception of linguistic structure, the past symmetric state of this structure (argument structure) is inferred to have resulted from a single, simplex transformation (projection only).

To illustrate what I mean, consider a structure to which both movement and projection have applied. Reconstructing the past symmetric state of the structure must involve removing the asymmetries imposed by both of these transformations. Crucially, this needn't be accomplished by re-applying both movement and projection. Rather, the effect of re-applying projection alone is enough to undo the effects of both movement and projection. This is illustrated in Figure 9. The leftmost object has been derived via projection of functional structure from the lexical item H0 and movement of the complement of H0 (YP) to a position higher in the structure. In each state represented to its right, one layer of functional projection has been removed under an iterative application of the projection transformation. Note that as a side effect of this process the moved constituent YP also gets closer and closer to its original position in the argument structure. As each layer of functional structure is removed, YP becomes adjoined to the next lowest functional projection until there are no more and it is reconstructed to its original position in the lexical item's argument structure.

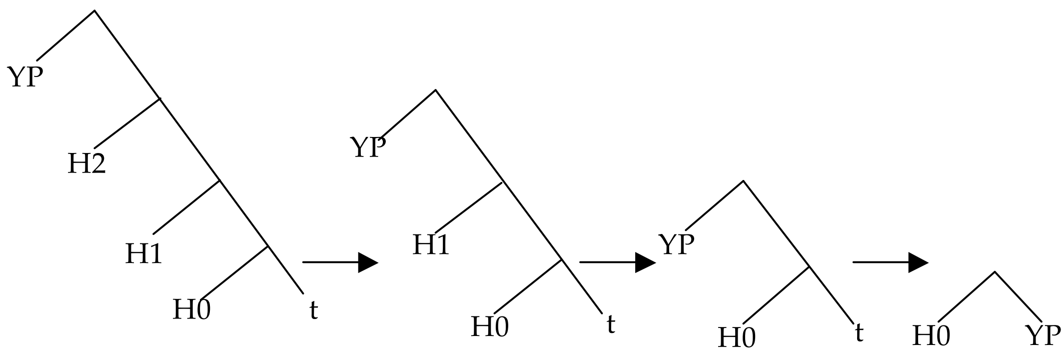

Figure 9: Removing effects of projection also removes effects of movement

I propose that this conflation of the effects of movement and projection in the perception of linguistic structure is responsible for the interpretative effects of successive-cyclic movement. As a side effect of inferring the past symmetries of argument structure via pure projection, rather than via the combination of projection and movement that resulted in the obfuscation of those symmetries, we interpret a moved XP as being adjoined to every functional head in the clausal architecture.

Note that adopting this idea has led us to a position very similar to the uniform paths hypothesis: The moved element adjoins to every head between its original and final positions. However, in the present understanding this adjunction takes place at the level of perception and not in the construction of the syntactic representations. Crucially, the conclusion that perception requires moved elements to reconstruct in this iterative fashion says nothing about the way that the movement asymmetries were imposed in the first place. That is, though movement is reconstructed to its original position via the projection transformation, we may still maintain that a unique movement transformation exists independently of projection and that this transformation is responsible for displacement. To put things in familiar syntactic terms, we may maintain that movement only occurs when it is triggered by an appropriate matching feature (say, a [wh] feature in an English question). Movement occurs in order to check this feature. With regard to syntactic derivation, this is all one needs to say. There is no need to posit intermediate movement positions between the original and final landing place of the moved constituent (but see below). Rather, movement can take place in one fell swoop. It is only in the perception of linguistic structure, when asymmetries are removed from the system, that the cyclic effects of movement are derived.

Of course, this understanding of successive-cyclic movement makes an important prediction about the sorts of effects movement should produce.[20] Since

[20] A reviewer inquires about the implications of the present approach for island effects. The implications are not obvious as island effects are a challenge for any theory of locality. However, the present approach at least suggests that one way to think of (some) island effects may be as a failure to infer past states. We might therefore ask what sorts of factors

I have claimed that the cyclic component of movement occurs in linguistic perception and not in production, the only effects of cyclic movement should be interpretative effects. That is, we shouldn't see any phonological or morphological effects of successive-cyclic movement (or even syntactic effects of a particular kind). While it is true that syntactico-semantic arguments are the most prominent in work that argues for the uniform paths approach to S-C movement, in fact, there are a wide variety of claims for morpho-phonological effects of S-C movement in the literature. Unfortunately I haven't the space to review them all here (see Boeckx 2007: chap. 2 for an overview); instead, I will simply note two general observations that would seem to be compatible with approach developed here. First, as Boeckx (2007) notes, the phonological and morphological evidence for successive cyclic movement is much weaker than the syntactic and semantic evidence, chiefly because it may be interpreted in a variety of ways. For instance, so-called wh-agreement effects seen in languages like Chamorro (Chung 1994, 1998), Kinande (Schneider–Zioga 2007), and Irish (McCloskey 2002) have been argued to constitute phonological evidence for intermediate wh-movement wherein intermediate verbs or complementizers agree with a wh-word undergoing S-C movement on its way to its final landing site. However, these effects could alternatively be analyzed as a series of agreement relations between features of verbs or complementizer and the wh word before movement of the latter takes place (see, e.g., Schneider–Zioga's 2006 analysis of the Kinande facts). In other words, these agreement effects do not necessarily provide evidence for successive-cyclic movement.

Second, I would like to point out that the vast majority of (non-semantic) evidence for successive-cyclic movement is really only evidence for movement through intermediate [Spec,CP] positions. Complementizer agreement facts like those mentioned for Irish and Kinande as well as subject-auxiliary inversion in embedded clauses in French (Kayne & Pollock 1978) and even subject alternations in Ewe (Collins 1993) are all effects that, if they are evidence for intermediate movement, can only be related to intermediate movement of the moved element through intermediate [Spec,CP] positions. The same is true for the most convincing evidence for successive-cyclic wh-movement, namely the wh-copying that occurs in languages like Afrikaans (du Plessis 1977, Felser 2004). In such languages, a wh-word fronted to the beginning of the clause is sometimes repeated in intermediate [Spec,CP] positions. An example appears below:

(5)	**Waarvoor** dink julle **waarvoor** werk ons?	*Afrikaans*
	wherefore think you wherefore work we	
	'What do you think we are working for?'	(du Plessis 1977: 725)

In this case, it is indeed difficult to think of an analysis that does not require intermediate movement through these positions in narrow syntax, that is, on the production rather than just the perceptual side of things. However, note that if

might prevent the reconstruction of moved elements via pure projection in the manner discussed here. Exploring this question fully is beyond the present paper, so I leave it for future work.

this is granted, it only reintroduces successive cyclic movement into the derivation in a limited and conceptually-justified way, namely as movement through [Spec,CP] positions. Importantly, of all the nodes in the syntactic architecture through which punctuated S-C movement might be required to pass through, [Spec,CP] is surely the least stipulative since it corresponds to a natural barrier of syntax, namely the topmost level of the extended projection (the clause level). If indeed this is true, as wh-copying phenomena seem to suggest, then we are forced to keep successive-cyclic movement, but only in a very limited and punctuated form that derives from a natural locality imposed by the size of the clause's extended projection. We still predict that movement should not have intermediate phonological or morphological effects that derive unambiguously from successive-cyclicity at any level other than the CP level.[21] Rather, only interpretative effects for these intermediate movements should be found.

Taken together, the present view has the surprising conclusion that in the debate between punctuated and uniform paths approach for S-C movement, both turn out to be correct, though in different domains. While the punctuated paths approach, restricted to the natural barrier of the CP level, characterizes the production of syntactic structure, the uniform paths approach characterizes its perception. As discussed above, this makes an important prediction: Morpho-phonological effects of S-C movement should be limited to evidence for movement through intermediate [Spec,CP] positions while interpretative effects of S-C movement should be unrestricted, giving evidence for movement through all intermediate positions. To the extent the data bear this out, the present approach is superior to the pure production-oriented views of S-C movement discussed above since those approaches must explain why some positions are more highly privileged than others: The punctuated approach must explain why elements move to some positions and not others, while the uniform approach must explain why morpho-phonological traces of S-C movement are limited to intermediate CP positions.

5. Conclusions

In this paper, I have argued that just as in visual computation, principles of symmetry and economy play a strong role in the computation of linguistic structure. It is crucial to note, however, that these two computational systems differ in an important respect: While the visual system is almost wholly concerned with perception alone (it is unclear what the 'product' of the visual system

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[21] As reviewers point out, the conclusion that [Spec,CP] is a 'natural' barrier in this way reinstates the notion of phases, at least lending support the idea that C is a phase head. I would not go so far, but clearly I have at least reintroduced the significance of a notion like Chomsky's (1986) 'Complete Functional Complex,' the level of structure at which all functional roles are satisfied. My position is that such a notion has significance because (i) there is overt syntactic evidence that this position is relevant for intermediate movement, and (ii) it is a conceptually natural syntactic object. However, whether the notion has significance beyond this (e.g., for a general theory of phases or extraction effects such as islands) is a separate research question that I will not go into here.

might be), the linguistic system is both a perceptual and productive system, and I have argued here that though both sides of the system make use of the same sorts of principles of symmetry and economy, exactly how those principles apply to production and/or perception may subtly differ. It is therefore possible that certain phenomena for which it is difficult to find a natural implementation in the productive system might find a more natural account in the perceptive system (and possibly vice versa). I have argued that successive cyclic movement is such a phenomena: While movement through intermediate [Spec,CP] positions can be naturally implemented in the productive system, evidence for movement through other intermediate positions should be interpreted as a by-product of the perceptual system alone. In large part, this lines up with the available semantic and morpho-phonological evidence for intermediate movement.

Another purpose of this paper was to suggest that some of the principles responsible for visual perception have been exapted for the perception and production of linguistic structure. In particular, I have argued for a central role for the dilation and translation transformations in the building and perceiving of linguistic structure. Given the basic character of language as a system that combines lexical items to form larger structures, it is easy to see why these two transformations in particular would be useful as exaptions: Dilation expands the representational space of linguistic structure and translation allows lexical items to be rearranged within that structure. Whether or not other components of basic group theory that seem active in visual perception (e.g., rotation, reflection) might also be active in the perception and creation of linguistic structure is an open question that requires attention.[22] Other questions also arise, in particular why is it that human minds employ such principles at all? Shepard has controversially addressed the latter question, arguing that the human mind makes use of principles of kinematic geometry because these principles have been extracted from environmental experience and 'internalized' in the course of human evolution. However, many have pointed out that principles of pure kinematics are seldom observed in the natural world where motion and shape tend to be messy and highly asymmetric. It is therefore hard to see why such internalizations would be favored by natural selection; that is, how such principles could be seen as adaptations to properties of the natural environment. It may be more likely that explanations will be found in more purely mathematical models of common organizational rules, such as those found in group theory, as Foster (2001) suggests. If that is the case, then evolutionary explanations in terms of the internalization of external regularities seem even more difficult to maintain. Rather, it may suggest that the various modules of the mind (language, perception, etc.) share common emergent organizational principles that can be described in mathematical terms, inviting more extensive and explanatory psychological descriptions along mathematical lines.

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22 Reflection comes to mind, for instances, when considering the structures involved in Parallel Merge (Citko 2005) and object sharing (Hiraiwa & Bodomo 2008) as well as in the general binary nature of hierarchical structure (see brief discussion of Kayne 1994 and Moro 2000 above).

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