Reps and representations: a warm-up to a grammar of lifting

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Abstract In this paper, I outline a grammar of lifting, i.e., a system that can generate meaningful, well-formed, and optimal movement patterns in resistance training. More specifically, I describe what the architecture of said grammar looks like, i.e., what levels of representation are needed and how these levels are organized, and, while doing so, I provide some examples of how representations generated at these levels can be modeled formally. To be able to do so, I adopt a goal-based conception of meaning, which allows us to talk about mappings from complex goals to complex surface outputs in systems of human behavior, signaling and non-signaling, interactive and non-interactive, in a unified way. I first motivate the existence of such meaning in lifting and subsequently argue that in lifting, like in language, meaning–form mappings are mediated by syntax, i.e., a level that operates on abstract and non-linearized hierarchical representations. This paper, thus, serves a double purpose. First, it provides further evidence for a universal tendency in human cognition, whereby mappings from complex goals to complex surface outputs are mediated by syntax. In this respect, this paper follows similar architectural claims made for frame sequences in pictorial narratives (Cohn 2020) and for single image pictorial representations (Esipova 2021), but it takes them beyond signaling behavior. Second, this paper showcases a specific methodological approach to outlining grammars of systems of non-linguistic behavior in humans. I take my cue from prior work with similar goals (e.g., Lerdahl & Jackendoff 1983; Hess & Napoli 2008; Katz & Pesetsky 2011; Fruehwald 2016; Patel-Grosz et al. 2018; Charnavel 2019; Schlenker 2019), but I approach the task differently, namely, by focusing on the larger architectural set-up before trying to flesh out any single level of representation in detail.

Contents

1 Introduction **2**
1.1 A grammar of lifting: why and how? 2
1.2 Structure of this paper 3

2 Meaning in lifting **4**
2.1 A goal-based conception of meaning 4
2.2 Potential for nonsense 6

2.3 Semantic vs. phonetic/phonological differences 9
2.4 Gradient vs. categorical distinctions and conventionalization of meaning–form mappings 12

3 Inverted Y model of grammar of lifting 13
3.1 Overview 13
3.2 Syntactic processes 17
3.2.1 Modification 17
3.2.2 Compounding 19
3.3 Syntax→form mapping 20
3.3.1 Linearization 21
3.3.2 Variable relative optimality of surface outputs 22

4 Further notes 24
4.1 Beyond a single rep 24
4.2 Prosody in lifting 25

5 Conclusion 26

1. Introduction

1.1. A grammar of lifting: why and how?

The "super-linguistic" research program seeks to expand the traditional object of study in linguistics in two broad ways: (i) including historically overlooked meaning-bearing aspects of spoken and written communication, such as hand gestures, facial expressions, prosodic modulations, emoji, etc. into our formal models of linguistic behavior (Lascarides & Stone 2009; Ebert & Ebert 2014; Ebert 2017; Schlenker 2018a,b; Esipova 2019a,b, 2020; Hunter 2019, a.o.), and (ii) applying the toolkit and the mindset of a linguist to objects that are not human language, namely, animal communication (see, e.g., Coye et al. 2017; Schlenker et al. 2017 for an overview), as well as non-linguistic systems of structured outputs in humans, such as pictures (Abusch 2012, 2019; Rooth & Abusch 2019; Greenberg 2018, 2019; Maier 2019; Maier & Bimpikou 2019; Cohn 2020; Esipova 2021, a.o.), music (Lerdahl & Jackendoff 1983; Katz & Pesetsky 2011; Schlenker 2019, a.o.), dance (Patel-Grosz et al. 2018; Charnavel 2019; Napoli & Liapis 2019, a.o.), yoga (Hess & Napoli 2008), and knitting (Fruehwald 2016).

The value of (i) for linguistics is incontestable, since these aspects of communication integrate into our utterances at all levels of representation in systematic ways that affect both their form and their meaning and simply cannot be ignored by linguists seeking empirical adequacy in their work. In other words, there is nothing "super" about this direction of inquiry—it is just plain linguistics.

The value of (ii), however, is somewhat less obvious, especially when it focuses on behaviors whose primary goals are not communicative in nature. It stands to reason that, say, pictorial communication, e.g., in pictorial narratives or information signs, or interpretative dance can share some properties with linguistic communication and can, thus, be studied using the same tools. But what about other systems of complex patterns of human behavior, such as non-interpretative dance? Even if we focus exclusively on surface outputs in

such systems, we can still study their systematic properties in comparison to those found in language in order to understand how certain universal tendencies manifest in different systems, as is done, for instance, for syllable structure in yoga in Hess & Napoli 2008, or for articulatory effort reduction in dance vs. sign language in Napoli & Liapis 2019. However, as I will argue in this paper, we can take it beyond the surface form and study the properties of meaning–form mappings in any system that involves systematic correspondences between complex goals ("meaning") and complex surface outputs ("form") in a uniform way.[1] This would further ground the super-linguistic research program within cognitive science, allowing us to fully explore its potential to inform our understanding of how the human mind works.

But to do so efficiently, we need to adopt an architecture-driven methodological approach. That is, when trying to outline a grammar of a given system, we should first and foremost aim to explicitly identify the levels of representation involved and how they interact with one another, which has not been done systematically in most work on non-linguistic behavior in humans cited above (with some exceptions, such as Cohn 2020). For instance, research on abstract hierarchical structures in music and dance, i.e., their "syntax", gleaned through observable surface structures, i.e., their "phonology" (Lerdahl & Jackendoff 1983; Katz & Pesetsky 2011; Charnavel 2019), has so far been conducted independently from research on meaning in music and dance, i.e., their "semantics" (Schlenker 2019; Patel-Grosz et al. 2018), and, crucially, without considering how these three levels of representation fit together architecturally—in stark contrast to how linguists have been studying language.

Thus, in this paper, I will use an explicitly architectural approach that, furthermore, relies on a goal-based conception of meaning to outline the grammar of *lifting*, a term that I use to refer to any form of resistance training, i.e., athletic activity aimed at increasing one's strength, endurance, muscle mass, etc. by putting extra tension on a contracting muscle with the help of one's body weight, free weights, resistance bands, weight machines, etc. Athletic movement, in general, is particularly well-suited for testing the universality of the goal-based conception of meaning and any specific properties of meaning–form mappings, as its primary goals have nothing to do with communication or even non-directed signaling and are, furthermore, relatively easy to identify—in contrast, for instance, to dance or music, whose goals can be much more complex and opaque. Furthermore, lifting is non-interactive and highly formulaic—in contrast, for instance, to combat sports—which makes it much easier to model.

1.2. Structure of this paper

In section 2, I introduce the goal-based conception of meaning as one that allows us to talk about meaning beyond signaling in a sensible way and argue that it can be applied to lifting. The first argument for the existence of meaning distinct from form in lifting comes from the potential for nonsensical patterns of movement, which are well-formed on the surface or are even composed of existing conventionalized exercises, but do not map onto any reasonable

[1]While Hess & Napoli (2008) do not directly talk about the meaning of yoga poses, Napoli & Liapis (2019) do attribute the differences in how effort reduction works in performance dance vs. performance sign to the difference in their functions. However, in this paper I will go beyond such broad, general effects that pragmatic considerations can have on phonetic and phonological processes and will instead focus on much more local phenomena, although I will briefly talk about how broad pragmatic considerations can affect the relative optimality of various surface outputs in lifting in subsection 3.3.

muscle overload goals (the equivalents of "blicks" and "colorless green ideas" from language). The second argument comes from the fact that, depending on the movement, the same surface contrast can be associated with a difference in muscle overload goals (i.e., it can be semantic in the proposed architecture) or not, instead being due, e.g., to articulatory considerations (i.e., it can be purely phonetic or phonological in the proposed architecture). At the end of this section, I also briefly discuss gradient meaning–form mappings and creation of categorical distinctions in the process of conventionalization in lifting and language.

I subsequently argue in section 3 that in lifting, like in language, meaning–form mappings are mediated by syntax, i.e., a level that operates on abstract and non-linearized hierarchical representations. The main arguments for this architecture come from the existence of systematic processes in lifting, such as modification and compounding, in which meaning–form mappings need to be formulated in abstract ways, and from the diversity and relative nature of sub-optimality in surface outputs arising from the same compositional structure. In this section, I focus exclusively on the structure of a single repetition (hf. "rep") of a given movement pattern within a set.

In section 4, I very briefly discuss some meaningful processes in lifting that happen at levels larger than a single rep and make a few very preliminary observations about prosody in lifting.

Section 5 summarizes the main points of the paper and outlines some directions for future research.

2. Meaning in lifting

2.1. A goal-based conception of meaning

While there is a long-standing tradition in formal semantics to model meaning in natural language in terms of truth conditions, not all meaning is truth-conditional even in language. In particular, we can produce linguistic expressions with the goal of expressing our immediate emotions or performing a variety of social functions, e.g., signaling something about your identity or building rapport with the addressee.

Imagine, for instance, that you drop something heavy on your foot and yell *Ouch!* or *Damn!* to let out your frustration. Intuitively, this is very different from you asserting *I am frustrated*. The latter assertion can be true or false and can, thus, be contested, despite its highly subjective nature. But in the former case, you are not trying to communicate anything that can be true or false (in fact, you are probably not trying to communicate anything to anyone at all in this case, as you likely don't produce this utterance with any addressee in mind, not even yourself). Non-truth-conditional meaning is, thus, non-negotiable. It is, furthermore, performative, i.e., you fulfil your expressive or social goals associated with a certain expression by virtue of uttering said expression; in a way, uttering the expression is the goal. These facts, in particular, have led Potts (2007) to formally analyze expressives as expressions that directly overwrite (a specific parameter of) the input context instead of contributing to the truth conditions, thus, capturing both the non-truth-based nature of expressive meaning and its performativity.

In addition, the two types of meaning seem to be treated differently by compositional semantics in that, unlike truth-conditional meanings, non-truth-conditional meanings don't have to interact with their surroundings semantically (Esipova 2020), thus, warranting dis-

tinct formal treatment at this level, such as in Potts 2007—contra any analyses that reduce non-truth-conditional meaning to some type or other of truth-conditional meaning, such as Potts 2005 or Schlenker 2007. However, truth-conditional and non-truth-conditional meanings often coexist within linguistic utterances and even within a single lexical item (e.g., in expressive degree modifiers like *The movie is damn good*). The expressions that carry truth-conditional and non-truth-conditional meanings do integrate with each other syntactically and/or phonologically in predictable ways, and while they don't have to interact with each other semantically, they still can. In other words, in language, truth-conditional and non-truth-conditional meanings come together within a single architecture of grammar, whereby we have systematic mappings between complex meanings and complex surface forms, mediated by syntax.

Thus, however we formalize truth-conditional and non-truth-conditional meaning contributions, we need a way to talk about them in a uniform way, and I propose that the way to do so is in terms of goals. Any utterance can be associated with a certain goal (or multiple goals). We assert things to communicate our beliefs about the world—and possibly to eventually change our addressee's beliefs. We ask questions to find out something about the world. We utter commands and requests to communicate how we want the world to be—and possibly eventually to bring the world in line with our desires. Some of these goals are associated with cooperative exchange of information, and, thus, it is quite natural to model individual utterances that pursue these goals in terms of truth conditions and the part of discourse that corresponds to such information exchange as an interactive endeavor that trades in questions under discussion, proposals that can be accepted or rejected, etc. But, as said before, expressive and social meanings are not meant to be negotiated, i.e., they are not part of this information exchange process. Of course, when someone utters an expression carrying such meanings, this can have various immediate conversational effects on external observers, e.g., they can get offended. Furthermore, an external observer can draw all sorts of inferences about the person who uttered this expression, which can be true or false—in the same way that we can draw an inference, rightly or wrongly, that it is raining outside when someone comes in in wet clothes—but this doesn't mean that we should be modeling the meaning of the expression uttered in terms of these inferences.[2] Note that in all cases, the act of uttering a linguistic expression immediately results in the context changing to one in which this expression has been uttered—and achieving that is the first step in achieving the more complex goals, such as making someone else change their beliefs or do something, or getting the answer to a question. It is just that expression of expressive or social meanings doesn't go beyond this first step.

More can be said about the goal-based conception of meaning in language. Among other things, we can think about if/how we want to talk about goal-based meaning in language compositionally. For instance, we can associate linguistic expressions that comprise utterances that partake in information exchange with goals of evoking concepts, constructing more complex concepts with more complex linguistic expressions and eventually building up

[2]Nor does it mean that we should ignore them. The disconnect between the meaning intended by the speaker and the conversational effects a given utterance can have, including the various inferences drawn by different external observers, can be drastic (e.g., in the case of slurs), and variation in such effects can be furthermore intentionally exploited by an aware speaker (e.g., in the case of dogwhistles)—thus, such effects should absolutely be modeled. We should just be very clear about what we are modeling.

to assertable content. This seems to go in the direction of the non-truth-based framework of meaning composition pursued in Pietroski 2018, but exploring this connection further is beyond the scope of this paper.

What I have said, however, should be enough for us to be able to talk about meaning in lifting. The nature of goals in lifting, of course, varies depending on the size of the structure we are looking at. As I said at the end of the Introduction, in this paper, I will primarily focus on goals associated with a single rep, although larger level goals will become relevant when we talk about relative optimality of surface outputs in lifting, and I will further briefly touch upon macro-level goals in subsection 4.1. Within a single rep, the goals we will be talking about will typically be to overload a certain muscle or muscle group in a certain way. For instance, the goal of a single rep of a standard bicep curl is to overload the bicep muscle through its full range of motion (ROM) while it's shortening (the goal of the *concentric phase* of the rep, which is typically harder) and lengthening (the goal of the *eccentric phase* of the rep, which is typically easier). As with expressive and social meaning in language, expression of meaning in lifting is, thus, performative, at least at this level: the goal of overloading the target muscle(s) is achieved as soon as the movement is performed.

I will talk more about how (sub-)goals map onto (sub-)movements within a rep in section 3. In the rest of this section, I will provide two arguments for the existence of meaning in lifting. The first argument comes from the potential for nonsensical patterns of movement in lifting. The second argument is based on the fact that changing a certain element of the surface structure can be associated with a change in muscle overload goals (i.e., a semantic change) in the context of one movement, but can be due to purely articulatory considerations (i.e., a phonetic/phonological change) in the context of another movement. I will subsequently briefly discuss gradient meaning–form mappings and creation of categorical distinctions in the process of conventionalization in lifting and language.

2.2. Potential for nonsense

We know that structural well-formedness, syntactic or phonological, is distinct from having a meaning or making sense. Thus, [blɪk] would be a phonotactically licit word of English—unlike *[bnɪk]—but it is not conventionally associated with any meaning.[3] The first stanza of Lewis Carroll's 'Jabberwocky' poem, composed of exclusively nonce roots, but using English grammar and functional morphemes, is an all-time favorite in intro to linguistics classes to showcase that a sentence needs not make sense to be syntactically well-formed (although the nonce words in 'Jabberwocky' do rely heavily on sound symbolism, so they are arguably not completely meaningless). Chomsky's (1956) *Colorless green ideas sleep furiously* is intended to make a similar point: even though it is composed of actual English words and is syntactically well-formed, our physical reality is such that it is hard for us to imagine an event witness that would make this sentence true under its literal interpretation in any world that resembles ours. In other words, given our world knowledge, this sentence makes no sense.[4]

[3]At least, it wasn't originally, when first introduced in Chomsky & Halle 1965. One could argue that it has by now acquired a meaning in linguistics as the prototypical nonce word, e.g., in the context of terms like *the blick test*.

[4]I sometimes hear people say that the 'colorless green ideas' example shows that syntactic well-formedness is distinct from semantic well-formedness, interpretability, or something along these lines. I would like to stress that compositional semantics has no problem interpreting this sentence. In fact, in order for us to

Similarly, we can have movement patterns in lifting that are biomechanically feasible and might even look like possible exercises on the surface, but to anyone who understands the kinesiological principles of resistance training, they make no sense, i.e., these movement patterns do not actually map onto any reasonable muscle overload goals. For instance, (1) demonstrates the "chest exercise" created by a social media personality and fitness brand owner Vince Sant a.k.a. VShred (this "exercise" was originally intended to be performed on a cable machine; (1) replicates it with a resistance band).[5] While on the surface it might look like a variation of the standard cable/band chest fly, shown in (2), the force vector created by the cable/band remains parallel to the arm throughout the movement in (1), i.e., no additional resistance is placed on the pectoral muscles, whose job is to move the arms across the body. In other words, as VShred doesn't actually "speak the language", i.e., he doesn't understand how meaning–form mappings work in lifting, nor does he seem to be able to properly tap into his mind–muscle connection to feel how much tension his target muscles are actually experiencing, he ended up creating a "blick" of an exercise.

(1) Meaningless chest "exercise"

(2) Standard chest fly

Next, while compounding existing conventionalized movements that target different muscles/muscle groups is in general a valid and common process in lifting,[6] which I discuss

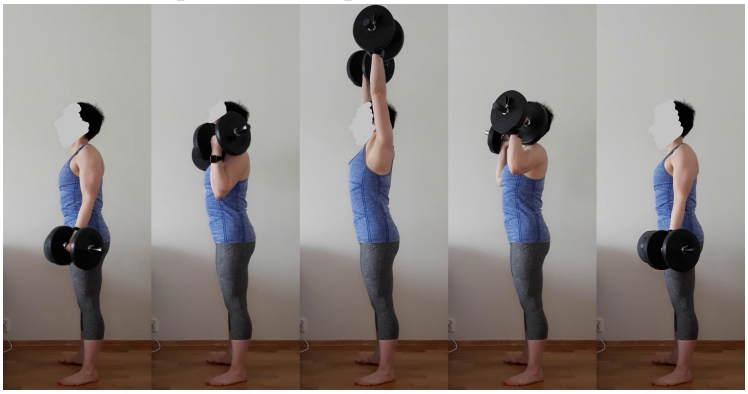
know that this sentence makes no sense, we need to first interpret it compositionally.

[5]VShred's original YouTube video presenting this "exercise" has since been taken down, following criticisms from the YouTube fitness community. See, for instance, this takedown by Jeff Cavaliere from Athlean-X for further details on why this "chest exercise" doesn't actually train the chest: https://youtu.be/dAlpe1eIYeM?t=116 (note: Cavaliere never mentions VShred in the video as the author of the "exercise"; instead, the video contains a recognizable parody of VShred performed by Jesse Laico).

[6]Note that the term *compound movements* is used in lifting to refer to any movement that recruits multiple muscle groups. Here I call such movements *complex movements* (when relevant), and I reserve the term *compounds* for combinations of already conventionalized movements, in a way that resembles

in more detail in subsection 3.2, some movement combinations make more sense than others. For instance, the combination of a dumbbell bicep curl with an overhead press (a.k.a. curl-press, or curl-to-press), shown in (3), is a meaningful combination of two movements that would use similar weights to properly overload the target muscles and would, furthermore, additionally engage the rotator cuff muscles during the transition between the two movements. It is also a functional movement pattern that can have uses in everyday life. In contrast, combining a bicep curl with a squat makes no sense from the perspective of resistance training. First, the lower body muscles targeted by the squat can handle much more weight than the biceps, so the lifter, limited by how much they can curl, wouldn't be properly overloading the squat portion of the compound. Furthermore, there is no specific reason to combine these two movements, as the two target muscle groups are neither complementary nor antagonistic, so there is no benefit to training them together within a single rep, nor is there any additional meaning created by the transition between the two or any ostensible practical use for this movement pattern. In other words, by combining a curl and a squat we have created a "colorless green ideas" of lifting.[7]

(3) Sensical compound: curl-press



(4) Nonsensical compound: curl-squat

compounding in language.

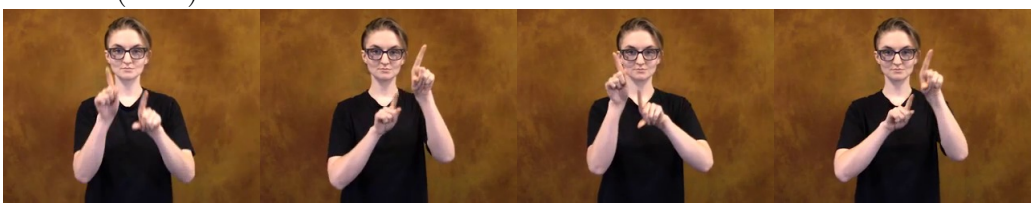
[7]Note that here I am not talking about sequences of heterogeneous movements that people can perform as reps within a set without trying to create additional meaning by combining specific movements or optimizing these sequences based on how much weight the various muscle groups involved can handle. One might in principle encounter a combination of a bicep curl and a squat within such a sequence, although they likely wouldn't be linearized as in (4). The overall primary goal of such training can be, for instance, to "burn calories" or to build cardiovascular endurance, so maximally overloading specific muscles/muscle groups would not be a primary consideration. While these training goals are, of course, valid, and such sequences can be well-designed for the training goals they are aimed to fulfil, I do not consider them compounds here.

2.3. Semantic vs. phonetic/phonological differences

In language, a certain contrast between two surface structures can be associated with different meanings, or it can be due to phonetic or phonological reasons.

For instance, palm orientation, in general, has a meaning-distinguishing potential in sign language, i.e., a (categorical) change in palm orientation is a phonemic contrast. For example, the American Sign Language (ASL) signs STARS and SOCKS in (5) are only distinguished by palm orientation, although palm orientation is not itself contributing a piece of meaning, i.e., palm orientation is not morphemic in this case. Palm orientation can be morphemic, however. For example, palm orientation in the ASL possessive pronoun in (6) is morphemic in that it encodes meaningful information about the referent (the palm faces the referent or the locus associated with it). However, a change in palm orientation can also be caused by articulatory considerations (e.g., depending on what other joints are involved when producing a given sign with a smaller or larger amplitude) or phonological processes (e.g., orientation assimilation in compounds or from the non-dominant hand to the dominant hand), and it can be subject to variation across signers (see, e.g., Liddell & Johnson 1989; Schembri 2001; Sandler & Lillo-Martin 2006; Pfau et al. 2012).

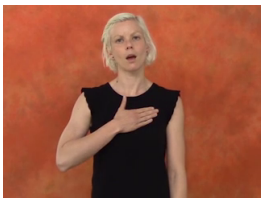
(5) a. STARS (ASL)[8]



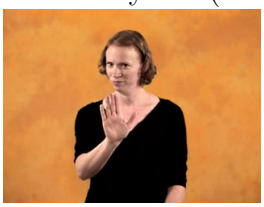
b. SOCKS (ASL)

(6) a. POSS-1 'my' (ASL)

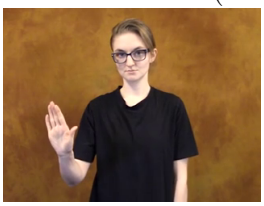
[8]Screenshots for ASL signs are from https://spreadthesign.com/



b. POSS-2 ‘your’ (ASL)



c. POSS-a ‘their’ (ASL)



Similar examples can be given from spoken language. /o/ and /a/ are two distinct phonemes in Russian and can distinguish between two words when they surface in their unreduced form under stress, e.g., /skot/ [skot] ‘cattle’ vs. /skat/ [skat] ‘ray (fish)’. The contrast between the two can also be morphemic, as Russian has monophonemic morphemes that are underlyingly /o/ and /a/, e.g., *šl-a* /ʂla/ [ʂla] ‘go.PAST-SG.FEM’ vs. *šl-o* /ʂlo/ [ʂlo] ‘go.PAST-SG.NEUT’. However, both /o/ and /a/ surface as [a] (or, rather, typically as one of its allophones, [ɐ] or [ʌ]) in certain environments in the process of vowel reduction, e.g., in the syllable immediately preceding the stressed one, as in /poˈʂla/ [pɐˈʂla] ‘go.INCH.PAST.SG.FEM’—which is a purely phonological process. Furthermore, the specific patterns of vowel reduction are subject to dialectal variation and can possibly be affected by other social factors.

Similar phenomena can be observed in lifting. For instance, changing the orientation of the grip between pronated and supinated on a pulling, rowing, or curling movement changes the anatomy of the movement in a way that affects the recruitment pattern for the target muscles and is, thus, associated with a change in muscle overload goals. Thus, the standard pull-up, with double-overhand grip, shown in (7a), will load the forearm muscles more, as compared to the chin-up, with double-underhand grip, shown in (7b), which will load the biceps more. A neutral/hammer grip (not pictured) on the pull-up will engage both muscle groups in a more balanced way. A mixed grip on the pull-up, shown in (7c), will target the two muscles groups asymmetrically (which can be desirable) and will add a further anti-rotational component to the movement. Changing the orientation of the grip also affects the ROM for the other muscles involved in the movement, in particular, the lats, which are the primary mover in all variations of the movement. Thus, the choice of grip on the pull-up affects its meaning. The grip contrasts on pulling/rowing/curling movements, thus, closely resemble the meaningful surface contrasts in language discussed above, especially the morphemic ones.

(7) a. Overhand grip on the pull-up

b. Underhand grip on the pull-up (a.k.a. chin-up)

c. Mixed grip on the pull-up

In contrast, changing the orientation of the grip on the barbell deadlift, whose compositional structure and various surface properties are discussed in greater detail in the next section (see (10a) for an illustration), between double-overhand and mixed isn't associated with different muscle overload goals, as this doesn't significantly affect the anatomy of the movement pertaining to the primary target muscles (knee and hip extensors). Instead, the choice of grip on the deadlift depends primarily on articulatory considerations.[9] Many lifters use the mixed grip with heavier weights, as it makes it easier to hold on to the barbell, even though it creates an unwanted asymmetry and is less safe (for one, it creates a higher risk of a bicep tear in the supinated arm). In addition, lifters might have existing muscle asymmetries, which can make them choose the specific version of the mixed grip (right overhand/left underhand vs. left overhand/right overhand) that they are strongest with for their heaviest sets. Finally,

[9]The trap bar deadlift, which employs a neutral grip, will target knee and hip extensors differently from the barbell deadlift, but that's due to a different weight distribution, not the change in grip orientation. Similarly, deadlifting with dumbbells will allow both for a more variable grip orientation and for a more variable weight distribution, but the two are independent of one another (beyond some obvious articulatory considerations).

social considerations can come into play as well, for instance, if a lifter thinks they look "cooler", more attractive, etc. when deadlifting with a specific grip. The grip contrasts on the deadlift, thus, resemble the contrasts due to phonetic or phonological considerations in language discussed above.

2.4. Gradient vs. categorical distinctions and conventionalization of meaning–form mappings

Note that the pronated–supinated distinction discussed in the previous subsection is gradient, and the muscle recruitment pattern of a given pulling/rowing/curling movement changes continuously in line with the grip change. This is also true for changing the width of the grip on such movements, changing the angle of the bench press to target the different parts of the pectoral muscles, changing the angle of the upper body on a Bulgarian split squat to target the anterior vs. posterior chain more, etc. In other words, in lifting, we often deal with an inherently gradient one-to-one mapping between form and meaning. This, of course, isn't the case for the natural language examples discussed in the previous subsection: phonemic contrasts are perceived as categorical, and so are the contrasts in meaning. Trying to produce something between /o/ and /a/ in /skVt/ in Russian will be understood as a sloppy instance of either /skot/ 'cattle' or /skat/ 'ray (fish)', not a word denoting a hybrid of a cow and a manta, or a cownose ray.

In this sense, such meaning–form mappings in lifting are closer to iconic gradient meaning–form mappings in linguistic communication, such as changes in movement path in classifier predicates in sign language or in gesture of non-signers.[10] This is unsurprising, since in both cases the mapping between meaning and form is non-arbitrary, and non-arbitrariness seems to be a pre-requisite for gradient meaning–form mappings (the reverse, of course, isn't true: not all non-arbitrary meaning–form mappings are gradient—that depends on the nature of the form and the meaning).

Interestingly enough, despite the inherently gradient nature of many contrasts in lifting, there is a clear tendency for creating conventionalized categorical distinctions, even

[10]See, e.g., Goldin-Meadow & Brentari 2017 for a discussion of categorical and gradient contrasts in sign. Note, however, that Goldin-Meadow & Brentari call gradient aspects of sign "gestural" and seem to furthermore assume they are "non-linguistic". I object to both characterizations. The use of the word "gestural" in this case doesn't match the layperson use of this word, which describes a certain mode of articulation in spoken communication that can be used to encode either gradient or categorical contrasts. This terminological choice, thus, might lead one to believe—mistakenly—that mode of communication directly and categorically prescribes the gradient vs. categorical nature of contrasts in this mode, and is, furthermore, spoken-language-centric. As for the tendency to label gradient meaning–form mappings "non-linguistic", it is, of course, omnipresent in linguistics, going back to Hockett 1959. However, the mere juxtaposition of "linguistic" and "non-linguistic" aspects of communication seems to presuppose the existence of a monolithic language module in human mind. Yet, language is a complex interconnected system that brings together multiple types of representations. We might be looking up some meaning–form mappings in a mental dictionary (these seem to always be categorical) and establish others via some iconic module (these can, but don't have to be gradient), but both types of meaning–form mappings can be used to expone parts of a coherent compositional structure within a single utterance. If anything, the fact that we can create meaning–form mappings on the spot and then know how to integrate them into our utterances in a systematic, predictable way is a testament to how complex and productive our linguistic ability is. Calling conventionalized meaning–form mappings "linguistic" and non-conventionalized ones "non-linguistic" is basically equating language with lexical semantics, but there is much more to language than that.

when no constraints are imposed by the equipment (e.g., pulling/rowing/curling movements performed with rings, dumbbells, cables/bands with single-hand attachments, etc.). For instance, the common conventionalized variations of the dumbbell bicep curl based on the grip orientation include: regular curl, with fully supinated grip; reverse curl, with fully pronated grip; hammer curl, with neutral grip; Arnold curl, going from fully pronated at the bottom to fully supinated at the top. The form of these is conceptualized as categorical, i.e., articulatory differences between individual reps are ignored, and the muscle overload goals are similarly formulated in a categorical fashion, e.g., "targeting the inner/outer biceps" or "targeting the forearms" or "loading the bicep throughout both flexion and supination simlutaneously"—even though the correspondence between the surface movement pattern and the actual muscle recruitment pattern is, of course, still perfectly gradient.

This is unsurprising, as resistance training relies on repeating the same movement patterns, and repeatability requires salient targets and more or less stable representations, which, of course, then get reinforced with further repetition. Arguably, this is also why conventionalization and creation of categorical contrasts goes hand in hand in language, as well, even in the case of non-arbitrary mappings, such as using a fixed number of repetitions to conventionally denote a plurality of individuals or events in speech, sign, or gesture (see, e.g., Schlenker & Lamberton 2019 on various repetition-based plurals in sign and gesture) or regularization of prosodic high degree modification (see Esipova 2019b on regularized prosodic high degree modification, as compared to simple segment lengthening to indicate increased length or duration).

A related shared consideration between the two domains is the role of substantial contrast, which is both needed for establishing categorical distinctions and, arguably, further reinforces their categorical nature. In language, contrast is crucial for us to be able to reliably distinguish between different meaning–form mappings, be it for the purposes of conventionalization or when juxtaposing two or more non-conventionalized meaning-form mappings within a single discourse situation, i.e., when we create a situational categorical distinction. In lifting, contrast plays a practical role, as well. There is little value in doing three variations of the same movement that only differ minimally, say, flat, 10% incline, and 10% decline bench press, since the differences in the muscle recruitment patterns across these three are negligible—as opposed to, say, flat, 45% incline, and 30% decline.

Now that we have seen that movements in lifting have meaning, let us talk about how exactly meaning–form mappings are organized in lifting, i.e., the grammar of lifting proper.

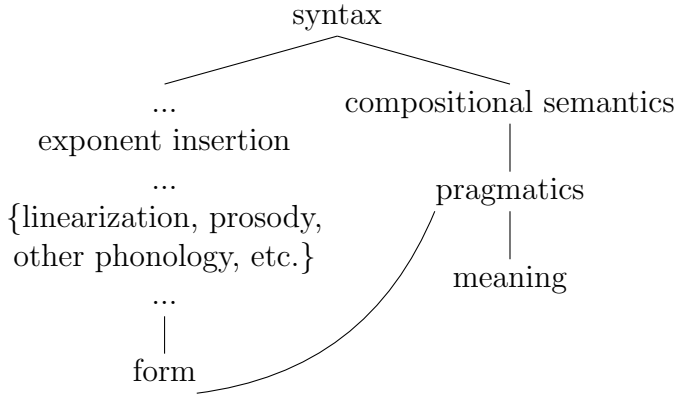
3. Inverted Y model of grammar of lifting

3.1. Overview

In the generative tradition, it is common to assume the inverted Y model of grammar for language, whereby meaning–form mappings are mediated by syntax, a level of representation that operates on non-linearized hierarchical structures. On the right side of the split, compositional semantics interprets the literal meaning of the syntactic structure, and pragmatics builds post-compositional meanings based on the output of compositional semantics, surface form of the utterance, various properties of the context, etc. via further reasoning about the mental states of the speech participants. On the left side of the split, linearization, creation of a prosodic structure, other phonological processes happen (possibly in several passes) to

eventually create a pronounceable surface structure. Certain theories of syntax→phonology mapping, e.g., Distributed Morphology (Halle & Marantz 1993 et seq.) or Nanosyntax (Starke 2010 et seq.), furthermore assume late vocabulary/exponent insertion, whereby syntax operates on abstract objects, and phonological exponents of specific parts of the syntactic structure get inserted post-syntactically as part of the syntax→phonology mapping. It is, furthermore, common to assume that compositional semantics doesn't have direct access to the surface output either (unlike pragmatics). A schematic representation of this model is given in (8).

(8) Inverted Y model of grammar of language



In this section, I will argue that a similar model is a promising way of modeling the grammar of lifting as well. In particular, I will propose that in lifting, too, meaning–form mappings are mediated by a level of representation that operates on abstract and non-linearized hierarchical structures, i.e., syntax. The main argument for the existence of such a level in lifting comes from the fact that there exist systematic processes in lifting, whereby the mapping between meaning and form is best formulated in an abstract way. Furthermore, I show that the relative optimality of various surface realizations of a given syntactic structure depends both on the biomechanics of a given movement (i.e., phonetic considerations) and on the relative weight of various pragmatic considerations, thus, once again, warranting the separation of the syntactic structure from the surface output, but allowing pragmatics to affect the latter.

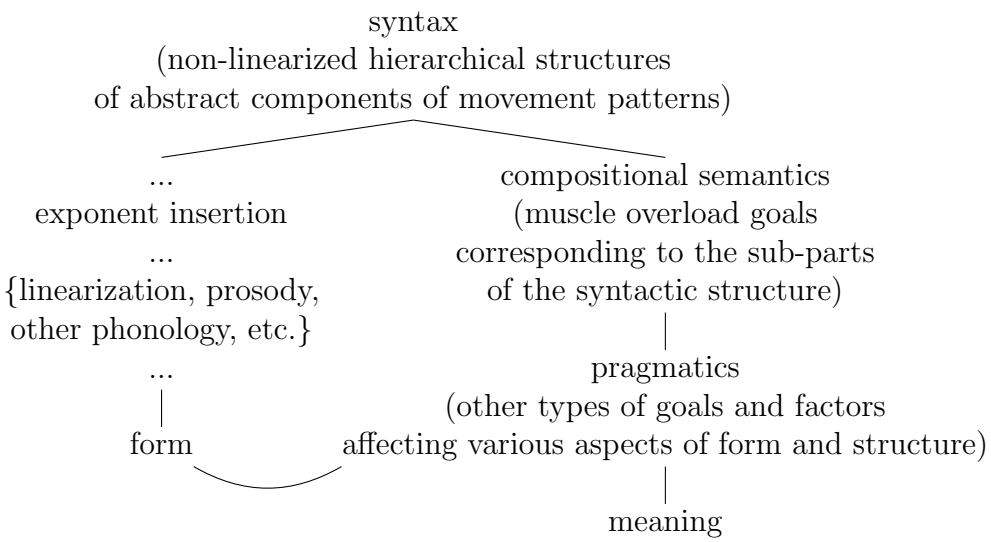
Note also that the model in (8) has important consequences for one's approach to multichannel expression of meaning. In particular, it entails that syntax and compositional semantics don't care about the channel of a given exponent, i.e., a given syntactic object can in principle be exponed through any channel.[11] Lifting also involves expression of meaning (i.e., realization of goals) via several channels, for instance, movements (i.e., "segmental" material) vs. intentional manipulation of tempo or duration (i.e., "suprasegmental" material), which I very briefly come back to in subsection 4.2. I believe that this at least justifies

[11]It also entails that there doesn't have to be a one-to-one mapping between the syntactic structure and the surface structure. For instance, one and the same syntactic object can get multiple surface realizations within one utterance (e.g., focus can be simultaneously marked via a pitch accent and a particle; certain high degree modifiers and affective meanings discussed in Esipova 2019b, 2020 can be simultaneously exponed via prosody and facial expressions, etc.), or even, depending on further assumptions, that pieces of the surface structure can expone overlapping, but non-identical pieces of the syntactic structure. It remains to be seen if anything like this happens in lifting.

keeping the late exponent insertion component of the model in (8) for lifting, although I will not be trying to argue that this is a crucial component of the grammar of lifting in this paper.

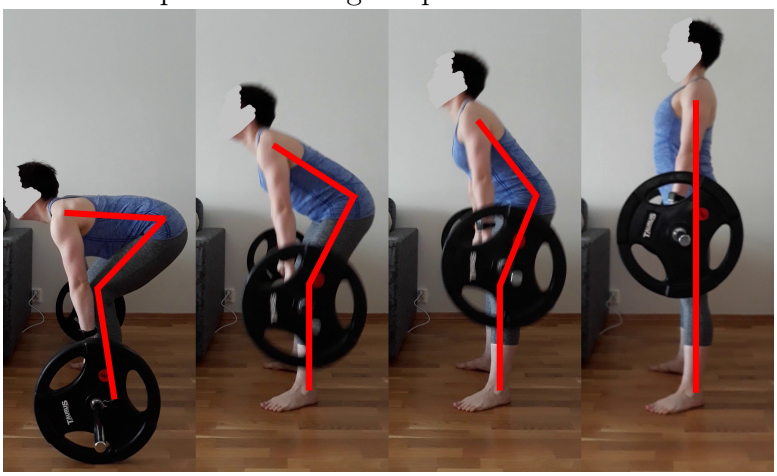
A schematic representation of the inverted Y model of grammar of lifting is given in (9).

(9) Inverted Y model of grammar of lifting



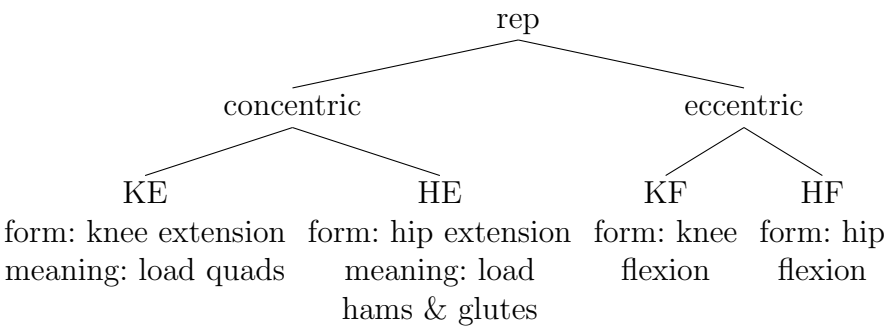
Before I proceed to discussing the arguments in favor of this model, let me provide a quick example of what the syntactic structure of a complex movement pattern can look like. In (10b), I give a very simplified syntactic tree for a single rep of the conventional deadlift, whose concentric phase is shown in (10a) (the eccentric phase is just reversing the movement).[12]

(10) a. Concentric phase of a single rep of the conventional deadlift



[12]Here, I do not associate the eccentric phase with any meaning, i.e., muscle overload goals. The received wisdom is that the eccentric phase of the conventional deadlift is there to simply get back to the starting position and should be performed as quickly as possible, while maintaining control over the weight. This is not the case for the variations of the deadlift, such as the Romanian and the stiff-legged deadlift, that do not involve putting the weight back on the ground between reps and do, in fact, aim to overload the eccentric. Also, I only focus on the dynamic components of the deadlift and completely ignore the isometric contractions here.

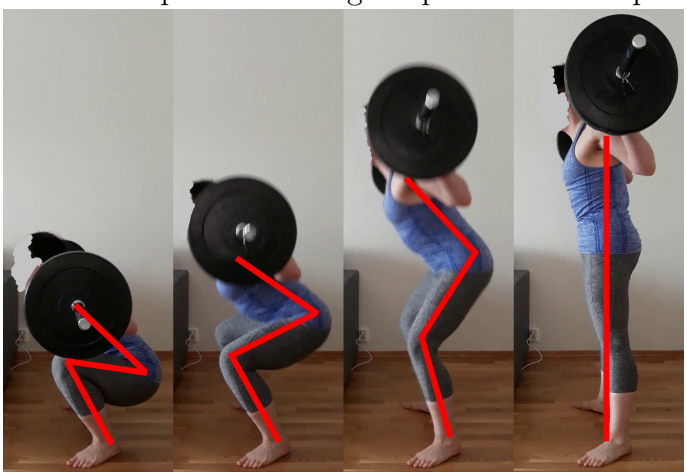
b.



In cases of simple composition like in (10b), the meaning of the mother node is just the conjunction of the goals of its daughters, but we will see instances of more complex compositionality in the next subsection.

Now, of course, 'knee extension' and 'hip extension' are not very informative specifications of the phonological content of the nodes. For instance, (11) shows the concentric phase of a single rep of the back squat, which has the same syntactic structure as in (10b).

(11) Concentric phase of a single rep of the back squat



One observable difference between the squat and the deadlift is the relative linearization of the concentric and eccentric phases within a rep: the former precedes the latter on the deadlift; the reverse holds for the squat. Remember, however, that the structure in (10b) is not meant to be linearized, despite what the inevitable 2D nature of tree representations might suggest, i.e., under the proposed model, this is not a syntactic or semantic difference between the two. I come back to issues of linearization in subsection 3.3.1.

The other major difference is that, due to the position of the weight and consequent weight distribution, the deadlift involves more of the hip hinge movement and less of the knee hinge movement, as compared to the squat, making it a more posterior chain oriented movement.[13] In a more elaborate representation, this difference would be captured by specifying the start and the end position of the relevant body parts. I will not attempt to come up with a system of formulating such representations here, but I will note a couple of things in this

[13] And, as mentioned before in footnote 9, the trap bar deadlift will have a weight distribution and subsequent knee/hip hinge ratio that is more similar to that of the squat.

respect. First, these representations need to be formulated in sufficiently abstract terms, as the exact angles will depend on the lifter's body proportions (and the height of the plates in the case of the deadlift) and will likely have to reference various external objects, such as pieces of equipment. Second, an interesting relevant question is if/how a given lifter's mental phonological representations for various movement patterns are affected by the training cues they used when learning them.

3.2. Syntactic processes

3.2.1. Modification

While lifting is very formulaic and relies heavily on lexicalized exercises, there is place there for creative processes. New exercises can be created from scratch or as innovative variations of existing exercises. More importantly for our purposes, however, there exist modification patterns that, once learnt, can be productively applied to new cases. Crucially, certain modifications can be applied to different parts of the movement, depending on one's specific goals, and, furthermore, the exact surface outputs resulting from these modifications will vary depending on the biomechanics of the movement being modified, in a way reminiscent of phonologically conditioned allomorphy in language—all while the underlying principle remains the same. In other words, when learning a new modification, a lifter learns a principle of creating new surface outputs, given a certain abstract hierarchical structure, not multiple unrelated meaning–form mappings. This favors a model of grammar that separates the abstract syntactic structure from the surface structure.

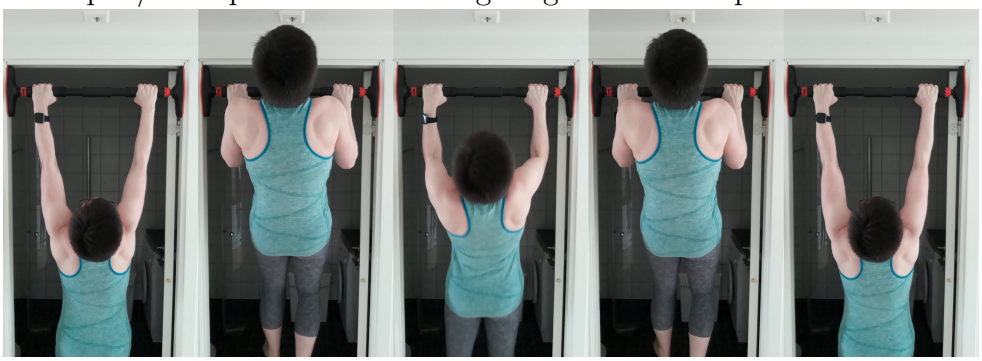
Let us look at some examples. One such productive modification is the "1.5-rep" modification, whereby the lifter goes through a certain portion of the ROM twice within a single rep to increase time under tension for the target muscle(s) in that portion of the ROM. The specific portion of the ROM thus targeted will depend on the specific goals of the lifter; e.g., it can be the hardest portion of the ROM, or the easiest (and, thus, systematically underloaded), one in which they want to improve their technique, one that emphasizes a specific muscle (group) in a complex movement, etc. Yet, in all these cases, we have an abstract shared meaning component.

Furthermore, where the target portion of the ROM is in the linear structure will depend on the biomechanic properties of the specific movement (and, in some cases, on the individual properties of the specific lifter)—not unlike how the exact form of a partially reduplicated item in a given language depends on the phonological properties of the input item and cannot be described in purely surface terms (e.g., the reduplicant might have to be the lexically stressed syllable of the input; the reduplicant could be truncated to fit a certain weight; the reduplicant can appear in various positions on the surface, depending on further phonotactic constraints of the language, etc.).[14] For instance, (12) shows the 1.5-rep modification aimed at increasing time under tension for the target muscle(s) throughout the hardest portion of the ROM, as applied to the pull-up, the squat, and the bicep curl. Of course, which portion of a given movement is subjectively the hardest one may vary across lifters depending on individual weaknesses, injuries, etc., but these portions are generally the hardest ones based

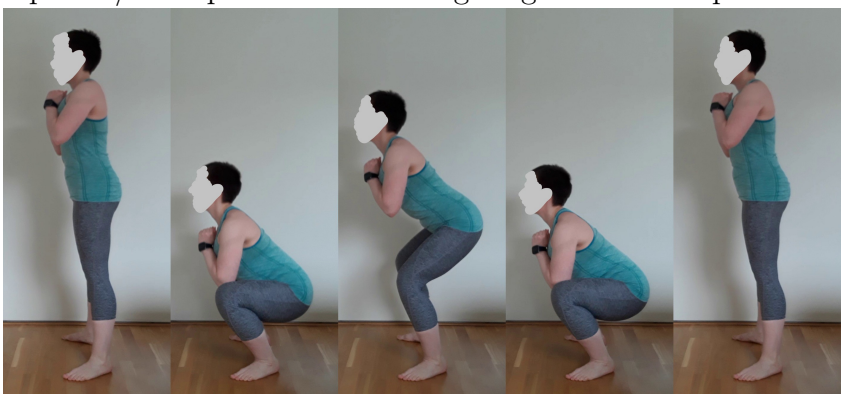
[14]The parallel with (partial) reduplication in language is particularly apt, given that it can be used to encode intensification of the input meaning, which, of course, is a meaning–form mapping with an iconic source.

on the strength curves for these movements.

(12) a. Pull-up w/1.5-rep modification targeting the hardest portion of the ROM



b. Squat w/1.5-rep modification targeting the hardest portion of the ROM



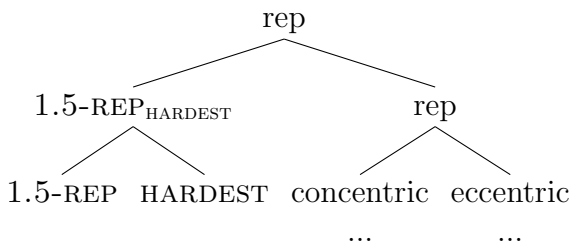
c. Bicep curl w/1.5-rep modification targeting the hardest portion of the ROM

The meaning of the modification, i.e., its goal, is the same in all the examples in (12). However, we would have hard time trying to formulate the rule for creating the surface output by only making reference to the linear surface structure, even if we allow ourselves to make reference to concentric vs. eccentric phases of a rep. In (12a), we do the following sequence: 1 concentric–1/2 eccentric–1/2 concentric–1 eccentric; in (12b), we do the reverse: 1 eccentric–1/2 concentric–1/2 eccentric–1 concentric; and in (12c), we reduplicate the mid-range of the ROM.

It is implausible that a lifter creates an ever-growing number of unrelated, counter-intuitively formulated direct meaning–form mappings for all these cases of 1.5-rep modifica-

tion. Instead, we could capture the regularities across all instances of applying the 1.5-rep modification by positing an abstract structure in (13), whereby an abstract 1.5-REP morpheme combines with a similarly abstract argument that further specifies which portion of the ROM the 1.5-rep modifier will reduplicate (e.g., HARDEST), and the resulting saturated modifier then modifies the rep of a specific movement. The result is a new syntactic structure of the rep, and we can then independently create a surface form for this entire structure based on the specific biomechanics of the input movement.

(13)



An example of a similar, but much simpler productive modification is the "paused rep" modification, where we simply introduce a "pause" into the compositional structure, i.e., an isometric contraction of the target muscle(s), which will also target a specific point of the ROM—typically one's "sticking point", whose surface position will once again depend both on the biomechanic properties of the movement and the lifter.[15]

Yet another example is the "cheat rep" modification, whereby we intentionally use momentum during the concentric phase (e.g., by swinging the weight up on the bicep curl or lateral raise, or by swinging one's chest up to the bar on the pull-up) and then slowly perform the eccentric, which allows overloading the concentric phase explosively, overloading the eccentric with a heavier weight, overloading the target muscle(s) beyond the point of failure, etc. The surface form of the movement, thus, changes quite a bit—the momentum component alone can drastically alter the muscle recruitment patterns of the concentric phase—and it would be, once again, hard and counter-intuitive to try to describe all these changes making reference exclusively to the surface structure.

3.2.2. Compounding

Another syntactic process in lifting I would like to briefly discuss here is compounding, which I already touched upon in subsection 2.2. As I said before, this is a process whereby we combine two (or more) existing lexicalized movements, often in a way that has some added benefits (e.g., recruiting additional muscles, training complementary or antagonistic muscles together, training a functional movement pattern, etc.), i.e., in a way that goes beyond

[15]This is one of the cases in which isometric contractions are actually meaningful and are, thus, part of the compositional structure. In fact, isometric holds can constitute the entirety of a movement; probably the best known example is the (static) plank. Of course, lifters constantly have to isometrically contract various muscles throughout various movements to maintain their body in a stable and safe position and to avoid energy leaks, without these isometric contractions being associated with any primary muscle overload goals—such isometric contractions are then just part of optimal surface outputs. That said, in some cases, it is not clear whether or not we should be including isometric contractions into our compositional structure, based on some potential secondary muscle overload goals of a given movement. For instance, the deadlift creates a lot of isometric overload for various muscles of the back—to the point where some consider it a "back exercise".

simply conjoining the goals of one movement with the goals of the other. This somewhat resembles how natural language compounds can have idiosyncratic meaning that goes beyond compositionally conjoining the meanings of the two parts, although, of course, the potential for added meaning in lifting is much more limited than in language.

With respect to surface form, similarly to natural language compounds, compounds in lifting aren't just linear sequences of a rep of movement X followed by a rep of movement Y. The exact surface form of a given compound, including the relative linearization of the various sub-components of the movements combined, will, as usual, depend on the biomechanic properties of the specific movements. Thus, the previously discussed curl-press compound, shown earlier in (3), sandwiches a full overhead press rep between the concentric and eccentric phases of a bicep curl rep; plus it also contains a transitional shoulder rotation movement between the two. Compare it to the squat-push-press, shown in (14), which combines a squat with a push-press, which is itself a modified, more explosive version of an overhead press incorporating an additional leg drive component. There the push-press component follows the squat component, but instead of doing a full squat rep, followed by a full push-press rep, the concentric phase of the squat transitions explosively into the concentric phase of the push-press, incorporating the "push", i.e., the leg drive component of the latter.[16,17]

(14) [Squat-[push-press]]

The model of grammar proposed here for lifting allows us to separate the syntactic process of compounding two movements from the meaning or form idiosyncrasies of specific compounds—just like we can do it for language.

3.3. Syntax→form mapping

Separating syntax from surface form in our model of grammar of lifting also allows us to capture the relative optimality of various surface realizations of one and the same syntactic

[16]On the surface, this is not entirely unlike movement reduction in sign language compounds, whereby two monosyllabic signs combine into a single monosyllabic compound, driven by the general tendency for monosyllabicity in sign languages (see, e.g., Sandler & Lillo-Martin 2006). Of course, in lifting, this process is much less regular, and it is not driven by an independent general tendency for monosyllabicity.

[17]Note that squat-push-press has a much better upper–lower body balance than the hypothesized curl-squat compound in (4), as the squat component is made harder by the need to generate the explosive force necessary for the "push", while the "push" makes the press component easier, so the more force the lifter generates with their legs on the squat, the more weight they can handle on the press.

structure, which can be affected by various considerations, both biomechanic and pragmatic.

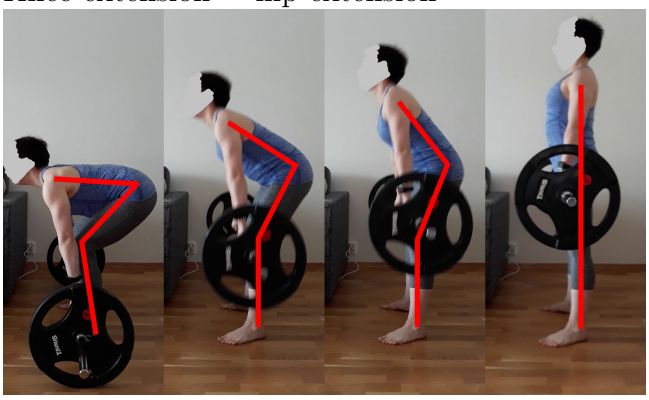
3.3.1. Linearization

Unlike in language, there are no ostensible reasons to posit categorical and/or arbitrary rules for linearization of syntactic structures in lifting.[18] Optimal linearization of the various movement sub-components in lifting is instead driven by biomechanic considerations.

For instance, in an optimally produced conventional deadlift, the knee and hip hinge components happen simultaneously, in a way that assures a vertical barbell path over the middle of one's foot and optimizes load distribution throughout the movement, as shown before in (10a) and repeated below in (15a). Starting hip extension before knee extension at the beginning of the concentric phase, before the weight leaves the floor, would be articulatorily impossible, but attempting to do so will likely result in a hip drop, putting the lifter in a disadvantageous position at the start of the movement, and extending at the hips faster than at the knees throughout the movement will disrupt the barbell path and compromise the lifter's balance. All these issues are shown in (15b). Extending at the knees too early, as shown in (15c), takes knee extensors out of the picture, increases the moment arm for the hip extensors, and puts more load on the lower back, making it harder to lift the weight and failing at properly fulfilling one of the original goals of loading knee extensors. In other words, doing so essentially turns the conventional deadlift into a stiff-legged deadlift off the floor; the stiff-legged deadlift is a perfectly valid exercise, but it has somewhat different goals from the conventional deadlift and would normally be performed with a lower weight.

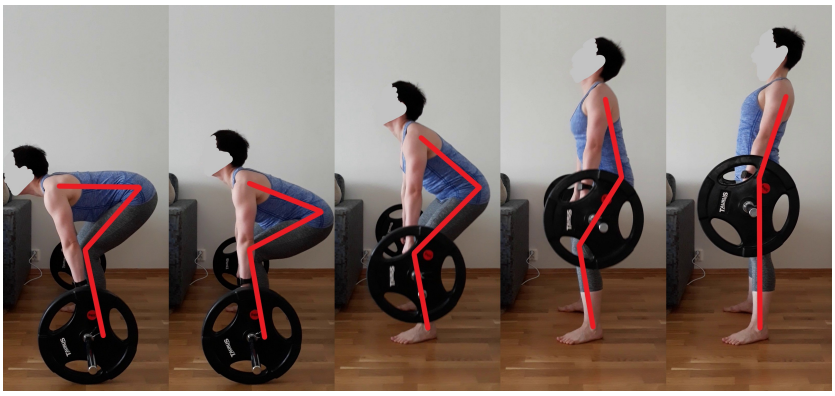
(15) Concentric phase of a single rep of the conventional deadlift: linearization

a. Knee extension = hip extension

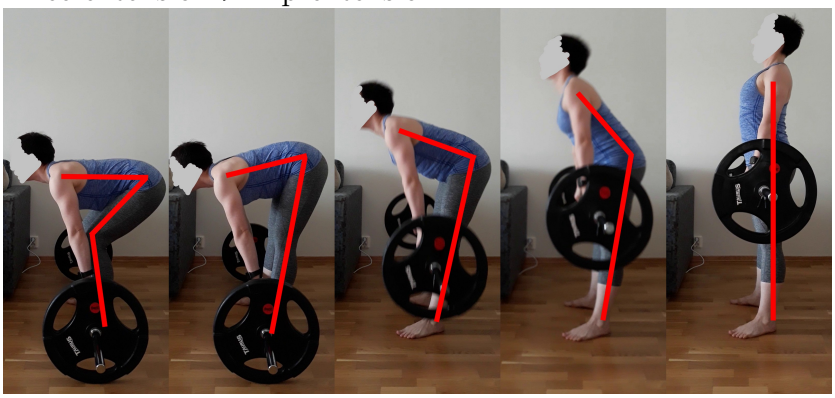


b. Hip extension > knee extension

[18] Arguably, not all linearization in language is categorical or arbitrary either, especially once we start looking beyond segmental material, but parameters like head-initial or head-final seem to be both categorical (for a given type of syntactic structure within a language, not necessarily for a given language across the board) and arbitrary.



c. Knee extension > hip extension



Linearization of the concentric vs. eccentric phase within a rep of a given movement is also determined by biomechanic considerations (and oftentimes common sense). For instance, the standard back squat starts on the eccentric rather than the concentric because (i) it is harder to get into position and properly brace one's core at the bottom of the squat, and (ii) starting on the eccentric allows one to use the stretch reflex at the bottom, which helps with getting through the sticking point of the squat. Very similar considerations explain why, for instance, the barbell bench press starts on the eccentric as well. However, both movements can be done from pins, starting on the concentric and bringing the weight to a dead stop on each rep, precisely with the goal of eliminating the stretch reflex and forcing the target muscles to generate all the power necessary to perform the concentric.

3.3.2. Variable relative optimality of surface outputs

While in (15) above, (15a) is incontestably the most optimal candidate, relative optimality of candidate surface outputs in lifting can vary depending on the relative weight a given lifter at a given moment of time places on various relevant considerations, such as lifting as much weight as possible, avoiding injury, avoiding aggravating an already existing injury, looking a certain way when performing the movement, etc. Following an existing tradition in natural language phonology (see, e.g., Pater 2009 for an overview), we could, thus, capture this process of maximizing optimality based on one's priorities via weighted violable constraints, allowing the weights of the constraints to vary across lifters and contexts.

For instance, in subsection 2.3, I have already talked about how the mixed grip on the deadlift creates both biomechanic advantages (ability to lift more weight, as the lifter is less limited by the strength of their grip) and disadvantages (asymmetries, higher risk of injury),

as compared to the default double-overhand grip. The choice of grip on the deadlift could, thus, be very crudely modeled as a competition between the 'overhand' and the 'mixed' candidate as evaluated against the two constraints in (16). SAFE penalizes any movement that increases risk of injury relative to some baseline, while AMWAP rewards any movement that allows the lifter to lift more weight relative to some baseline. I will not address the issue of how said baseline is established in any great detail. It can be done, for instance, by treating one of the candidates as unmarked, or by starting with 0 as the baseline for all candidates and assessing how much they increase the risk of injury relative to doing nothing, how much weight one can lift with this candidate relative to 0, etc. The strategy can in principle vary across constraints. Here I will assume that the 'overhand' candidate is unmarked and will be treating it as the baseline. I will furthermore assume that a constraint can positively or negatively affect the value of a given candidate by adding/subtracting 1 to/from it, multiplied by the constraint's weight coefficient W. Of course, in a more fine-grained model, the candidates will be evaluated against these constraints in a gradient fashion, but for the purposes of our toy derivation, a binary set-up is sufficient: a movement either triggers a constraint or it doesn't. The tableaux in (17) show how either the 'overhand' or the 'mixed' candidate can emerge as the maximally optimal one depending on the relative weights of SAFE and AMWAP.[19]

(16) a. SAFE (Be safe!): $-1 * W$ for every movement that increases the risk of injury relative to the baseline

b. AMWAP (Lift as much weight as possible!): $1 * W$ for every movement that allows the lifter to lift more weight relative to the baseline

(17) a.

/deadlift/	SAFE (2)	AMWAP (1)
☞ a. 'overhand' (0)	0	0
b. 'mixed' (-1)	-2	1

b.

/deadlift/	SAFE (1)	AMWAP (2)
a. 'overhand' (0)	0	0
☞ b. 'mixed' (1)	-1	2

The same toy derivation would work for deadlifting with a neutral back vs. with a rounded (upper) back. The former is in general considered the prescriptively proper form for the deadlift. However, rounding one's back will shorten the moment arm for the hip extensors and will once again allow the lifter to lift more weight, which is why we often see competitive powerlifters lift with a rounded upper back, as shown in (18).

(18) Powerlifter Konstantīns Konstantinovs deadlifting with a rounded upper back[20]

[19] The weights of the constraints are written in parentheses after their names (no other ordering mechanism is assumed), the value of all the candidates is originally set to 0, the numeric effect of a given candidate being evaluated against a given constraint is given in the appropriate cell of the tableau, and the final value of each candidate after being evaluated against all the constraints is given in parentheses after the candidate's description.

[20] Image source: https://stronglifts.com/deadlift/

Of course, professional strength athletes are also more experienced and can minimize the risks of lifting with a rounded back (and, in particular, avoid rounding their lower back, which is what causes an increased risk of injury). Thus, in the context of the model sketched above, it is not just that the weight of AMWAP is high for them, it is also that the effect back rounding triggers in SAFE is lower for them than for less experienced lifters.

4. Further notes

In this section, I will very briefly discuss some of the issues this paper chose not to focus on.

4.1. Beyond a single rep

So far I have talked exclusively about the structure of a single rep. Of course, reps are integrated into larger structures, as shown in (19).

(19) Basic (non-exhaustive) hierarchy of units in lifting:
rep > set > exercise session > training session > training mini-cycle (e.g., within a week) > training maxi-cycle (e.g., across several weeks)

Various meaningful and productive processes can happen at all these larger levels as well. Many of these processes aim to manage the distribution of training volume and intensity for various muscle groups over a given structure. For instance, there are various ways in which working sets (as opposed to warm-up sets, which, of course, also fit into a larger structure in a certain way) can be organized within an exercise session in terms of volume and intensity, e.g., flat, pyramid (start with more reps with lower weights and build up to less reps with heavier weights), reverse pyramid, etc. Various specific exercises are organized within and across sessions according to a specific "training split", which specifies which muscle groups are targeted on which days within a mini-cycle (e.g., "full-body", "upper-lower", "push-pull-legs", etc.). Finally, training volume and intensity can be managed in various ways across maxi-cycles as well.

Some processes applying at these larger levels will have more specific goals. For instance, when it comes to organizing reps within a set, one productive technique whose purpose is to extend the set beyond the point of failure is the "drop set", whereby the lifter performs reps with a certain level of intensity to failure and then immediately drops the level of intensity (e.g., by decreasing the weight or switching to an easier variation of the movement) and performs additional reps to failure. Another productive process, applying to sets, is "supersetting", when single sets of different exercises are performed back-to-back with little or no rest between them, thus, creating a complex set, which can then be repeated. Circuits in circuit training are basically large supersets. As with rep compounding, some supersets are

more coherent than others. For instance, it makes sense to superset tricep extensions with bicep curls (antagonistic target muscles, low intensity movements), but it doesn't make much sense to superset heavy squats with heavy deadlifts (similar target muscles, high intensity movements).

It remains to be seen to which extent we can use insights and tools from linguistics, and, in particular, discourse analysis to model such macro-level processes in lifting.

4.2. Prosody in lifting

Another topic I have not touched upon at all is prosody in lifting. There are a few questions one could ask in this respect. What do prosodic structures look like in lifting? Is there an equivalent of prominence marking? To what extent can prosody carry meaning in lifting? I will not aim to properly address any of these questions, but I will offer a few quick ideas that can be developed in the future.[21]

In terms of prosodic hierarchy, the largest potentially relevant unit seems to be a set, with reps being the most obvious smaller prosodic units. Rep boundaries are, in particular, relevant for the 'concentric > eccentric' vs. 'eccentric > concentric' linearization distinction and, in the case of heavy complex movements like the squat, the deadlift, the bench press, etc., for breath reset. Breathing, in general, is much more regularized and consciously controlled in lifting than in speech and, thus, presumably warrants its own tier in the phonological structure.[22]

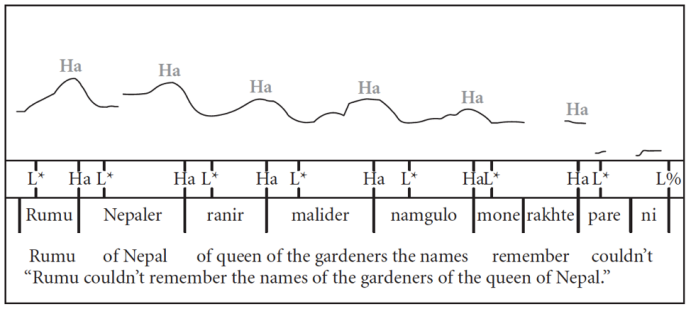
It remains to be seen if an intermediate prosodic unit is needed between a set and a rep. A rep, however, most likely needs to be further split into phases to properly model the processes that can hold between the concentric and the eccentric. It remains to be seen if the full rep and the half-rep within 1.5 reps need to be treated as yet another prosodic phrasing distinction or simply as four phases.

It might be tempting to draw analogies between prosodic structures in lifting and those in sign languages or in spoken languages with highly regularized prosodic phrase structure, such as Bengali in (20) (for instance, peak lengthening and shortening of the target muscle could be treated analogously to L and H tones and assumed to mark phase boundaries). It remains to be seen to what extent such analogies are justified.

(20) Structure of prosodic phrases in Bengali (Khan 2014)

[21] Here I am only talking about dynamic movements in lifting. Exercises consisting entirely of isometric holds, such as the (static) plank, arguably don't have much of a prosodic structure.

[22] Think, for instance, about how the Valsalva maneuver is often used by lifters on certain heavy lifts, such as the squat, to help create and maintain abdominal pressure throughout the lift, whereby the lifter takes a large breath into their belly before starting the rep, keeps trying to exhale against a closed glottis throughout the concentric phase, and releases the air after the point of maximum effort.



It is, furthermore, unclear to me if there is any equivalent of prominence marking in lifting beyond phrase-edge phenomena. For instance, endpoints of concentric phases that end in a peak contraction of the target muscle(s) are naturally prominent, and this prominence can sometimes be exaggerated, e.g., in an attempt to give the target muscle(s) an "extra squeeze at the top". At this point, it is not clear to me, however, if this should be treated as an instance of prominence marking, nor if other parts of a movement can be systematically accentuated, in particular, in a way that would be associated with a specific muscle overload goal.

What definitely does happen in lifting is manipulating tempo and/or duration in a meaningful way—as opposed to changes in tempo and/or duration due to, say, one's level of exhaustion. For instance, "cheat reps", mentioned earlier in 3.2.1, shorten the concentric and lengthen the eccentric. Intentionally slowing down the eccentric is, in general, a common way of increasing the overall time under tension for the target muscle and balancing out the load on the concentric vs. the eccentric. On the other hand, "speed reps", intentionally produced at a high tempo, can be used to overload the target muscles more explosively. Just like similar meaningful prosodic modulations in language (such as prosodic degree modification mentioned in subsection 2.4), under the model proposed in (9), modulations of this kind in lifting would be treated as exponents of abstract syntactic objects.

As with macro-level structures, I leave any further exploration of prosody in lifting for future research.

5. Conclusion

In this paper, I have attempted to outline a grammar of lifting, i.e., a system that can generate meaningful, well-formed, and optimal movement patterns in resistance training. To do so efficiently, I have adopted an architecture-driven methodological approach and a goal-based conception of meaning. I hope to have shown that despite the very different nature of specific goals and specific representations underlying linguistic behavior and lifting, there are similarities between the two in how the mappings between different levels of representation are organized.

In particular, I have used similar arguments as have been used for natural language to argue for (i) separation of structural well-formedness and meaningfulness, and (ii) separation of abstract and non-linearized hierarchical structures (syntax) from surface structures (phonology) in lifting. I hope that in the future we can test how architecturally similar these two systems actually are experimentally, for instance, by measuring reactions of experienced lifters to various types of anomalous outputs in lifting (e.g., reps with sub-optimally lin-

earized sub-components; movements that are biomechanically well-formed, but do not seem to map onto any reasonable muscle overload goals; compound reps combining well-executed meaningful movements in a way that doesn't make sense; sloppily executed movements, e.g., with an irregular tempo or an inconsistent range of motion across reps, etc.) and comparing them to similar data from language (in particular, from sign languages, which will hopefully eliminate some irrelevant modality effects).

To further test the universality of the various properties of mappings between complex goals and complex surface outputs that I have sought to identify in this paper, it would be worthwhile extending the same methodological approach to other non-linguistic systems. As I have already mentioned in the Introduction, I expect interactive athletic activities to be more challenging—but also very interesting—to model. For one thing, one would need to embed a grammar that generates surface outputs based on the agent's goals into a model of the participants' reasoning about each other's goals and subsequent behaviors, which would, furthermore, get even more complex once we go from two-participant sports to team sports. Going beyond athletic activities, it would be interesting to see if/how the goal-based conception of meaning can be applied to systems whose goal is to affect external objects rather than the agent's body, such as knitting. As a first approximation, the primary goals of specific knitting techniques and modifications have to do with creating objects with specific physical properties, in a way that could be potentially compositional, however, I am leaving a proper exploration of this idea for future research (by someone knowledgeable about knitting).

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