Actionism in syntax and semantics

First Author
Affiliation / Address line 1
Affiliation / Address line 2
Affiliation / Address line 3
email@domain

Second Author
Affiliation / Address line 1
Affiliation / Address line 2
Affiliation / Address line 3
email@domain

1 Introduction

In this paper, we present a view of "syntax" which is compatible with a perspective on perception called *actionism* (Noë, 2012). Actionism holds that perception is not a series of snapshots of scenes in the world leading to their inferential manipulation as representations in the brain as has standardly been assumed (Marr, 1982). Rather perception is engagement with the world, an activity and an achievement. As we shall argue in due course, the same perspective extends to natural language (NL). The motivation for this perspective starts with the assumption that, in order to survive, organisms have to play an active part in controlling their environment and keeping it within desirable states. For an organism to exert such control, there must exist predictable relationships between its actions and resulting perceptual stimulations since the purpose of perception/action is to ensure adaptability. Accordingly, any agent will benefit from actively exploring its material/social environment (or "habitat", Heft, 1989) for risks or opportunities and evolutionary processes ensure that no heavy burden is placed on the cognitive resources required. According to actionism, exploration and exploitation of environmental resources makes use of the agent's knowledge of sensorimotor contingencies (see, e.g, Buhrmann et al., 2013; Maye and Engel, 2011) instead of brain-internal inferential or representational means. Sensorimotor contingencies are lawful regularities in the dynamic relation between the agent and the habitat, patterns of dependence of changes in the sensory input as a function of an agent's movements (Gibson, 2014).Information about entities in the habitat and their potential for interaction is also mediated by the perception of complex regular patterns, *constraints* (Barwise and Perry, 1983), that can originate from social as well as natural learning experiences. Various such learned expectations are built up through reiterated interactions with entities and are then deployed in subsequent encounters with them. Perception of an entity will then be constituted by the set of expectations concerning the possible actions enabled by it (its *affordances*), rather than its association with a mental symbol and stored propositional knowledge.

1.1 Natural language as extended actionist perception

The general problem that has led to internalist inferential theories is that perceptual understanding is not confined to what is immediately perceivable: it is generally agreed that the agent's perceptual capacities provide access to more than what is directly recorded on the stimulus or the presumed sense data. For example, in vision, we experience the total presence of features of the world, e.g., we see familiar objects as wholes, even though some of their parts or properties might be occluded. We encounter the same phenomenon in language in that we normally understand much more than what is explicitly encoded in an utterance:

(1) (a) Eleni: Leaving? (b) Frank: End of the month.

We can also keep constant the experience of objects and their properties as they move through changing conditions, for example, we do not notice how the apparent colour of an object changes as we look at it moving from a bright environment outdoors to a less bright environment inside a building ('perceptual constancy'). Similarly, in NL use, speakers are usually unaware of the intricacies of the requisite syntactic/semantic coordination and the ambiguities and vagueness that decontextualised analyses of NLs present as problematic. For example, in dialogue, interlocutors frequently jointly develop a single unit by skillfully continuing each other's turns while seamlessly adapting to subsentential changes of contextual parameters and observing other-initiated syntactic/semantic dependencies across turns:

(2) {A emerging from a smoking kitchen}

A: I've almost burnt the kitchen down.
B: Have **you** burnt
A: **Myself**? No.

Actionism explains such properties of vision by emphasising its direct relationship to action: due to their sensorimotor knowledge, agents are capable of opportunistically pursuing relevant affordances that engage the habitat directly rather than aiming at the enrichment of intermediate brain-internal symbolic representations of the habitat prior to deciding on how to act to modify it. The role of the brain's contribution is taken as a necessary but not sufficient factor in perception. The individual brain has considerable plasticity and capacity to support diverse and externally distributed behavioural repertoires through the temporary creation of nested and overlapping neural assemblies in which each element is participating in various coalitions with other elements at different times (*neural reuse*, (Anderson, 2014)). Generalising this view, we argue that, at any type of engagement with others or the environment, an agent acts-to-perceive the predicted consequences of its interactions instead of refining representations of these interactions to serve as guidance for its action. Such predictions are generated by means of the agent's embodied sensorimotor knowledge of how its own various movements change features in the world and by what is licensed within the current sociomaterial context. Given that such predictions inevitably (partially) fail, cultural practices afford groups of agents online strategies for intervening and adjusting the landscape of affordances to the combined needs of the agents involved:

(3) (a) A: How would'ja like to go to a movie later on tonight?
(b) B: Huh?=
(c) A: **A movie** y'know like **a like ... a flick?**
(d) B: Yeah I uh know what a movie is (.8) **It**'s just **that=**
(e) A: **you don't know me well enough?** [from (Sacks, 1992)]

1.2 Conceptual understanding

Unlike existential phenomenology (Dreyfus, 2013) and related views, in actionism, sensorimotor knowledge implicates conceptual understanding from the earliest stages of perceptual access. However, conceptual abilities do not, as in standard models, proceed via an intermediate cognitive stage before initiating the control of action. Concepts, under this view, are not the rich internal representational structures of standard views of the mind and cognition. Linking concepts exclusively to propositional judgements either in a direct (Kantian) way or an indirect (Fregean) way is inadequate from this perspective because, it is argued, there are other non-belief-involving modes of activity where agents display conceptual abilities (e.g., mundane everyday unreflective perception, reading in a familiar language, interacting with dogs, keeping appropriate social distances, etc.). For example, in perceiving some entity and identifying it as a dog, it is not a static retinal image that becomes associated with the application of the concept. Instead, it is a pattern of current and past interaction that differentiates the entity and, eventually, identifies the pattern currently interacted with as a particular set of affordances pertaining to the existence of a dog (Bickhard and Richie, 1983a, p.23). On this view, conceptual understanding cannot be taken as static pattern-matching but is, instead, an achievement. It is time-extended, incremental, and based on trial-and-error rather than an automatic mapping of experience to internal categories or propositional knowledge.

Moreover, due to their basis in action, concepts are necessarily always fragile and incomplete: in general, the specification of action must allow flexibility to fit different situations and changing conditions and, therefore, successful situated action execution depends on leaving some degrees of freedom unbound (Suchman, 1987). But both these degrees of freedom and the variety of multiple affordances in the human habitat introduce complexity due to the fact that agents do not perceive only one affordance at a time. Humans always perceive a continuously restructured dynamic field of affordances that consists of various possibilities for action soliciting attention. Cisek & Kalaska (2010) propose that 'affordance competition' is resolved by humans and animals through active moment-to-moment exploration of the field of available affordances without realising an overall plan of action but by being drawn towards the most rewarding predicted outcomes. Rietveld et al. (2018) have proposed that the "solicitation" of multiple complex affordances towards humans can be modelled as triggering states of action readiness. Perceiving complex nested structures of affordances and developing appropriate action readiness requires training, i.e., developing skills, especially through participation in 'practices', i.e., coordinated patterns of behaviour of multiple individuals. Individuals or groups of individuals can then respond selectively to relevant (sets of) affordances in each particular situation because they act under the guidance of affective

tensions, emotional responses like feelings of discontent or dissatisfaction, modelled as systemic disequilibriums during interaction. Such feelings are induced by the discrepancies between a concrete situation and the embodied skills of perceiving the norms of the situation type that have been acquired by training. Agents resolve such tensions by resorting to their expertise. Their familiarity with the interactive environment allows them to intervene and restore perception of the expected affordances of the situation type (see e.g., the practices of (non-sentential) clarification and correction in (3b,c)) or adjust their expectations to differentiate a new situation type (e.g. proactively attempting to preempt social awkwardness in (3e)).

1.3 NL grammar as (inter-)action coordination

To date, like the standard views of perception which actionism seeks to replace, formal theorising about natural language (NL) has typically retained its characterisation as a code, an abstract system of rules and representations arbitrarily mapping forms to concepts conceived as symbols in a language of thought. In this paper, we argue instead that NL is first and foremost coordinative action both with respect to the environment and other individuals and we propose a grammar formalism defined directly in terms of such actions.

We take individual utterances as primarily physical events having effects (as stimuli) on human agents, both the utterer themselves and the perceiver (the addressee or any side-participants). Utterances can be further characterised as *actions*. Actions are physical movements realising goals (we include mental actions in this characterisation since, arguably, they are also realised by physical events within individual brains or social interactions). These goals are not formulated via the standard notions of (Neo-)Gricean intentions or plans but are, in fact, mostly, subpersonal, non-propositional, and unreflective, induced and resolved via affective tensions and expert know-how. As with perception, flexibility and efficiency requires that action specifications at various levels be partial so that the organism can adjust to its changing environmental circumstances. For example, efficient NL perception/production in dialogue is opportunistic at the subsentential level exploiting and exploring immediately what is made available by the interlocutor's basic micro-actions:

(4) (a) Angus: But Domenica Cyril is an intelligent and entirely well-behaved dog **who**

(b) Domenica: **happens** to smell [BBC radio 4 play, 44 Scotland Street]

Of course, humans can form explicit goals and plans (propositional *intentions*), but even these, in order to be executed, have to be broken down into component subpersonal goals. Usually, there is no one-to-one correspondence between a high-level intention and the implicit small-scale means (mechanisms) employed to execute it. The means employed to execute subgoals need to be responsive to what is available in the context and this availability not only can modify explicit intentions, in fact, it is the very background for the generation of goals and intentions in the first place (Wittgenstein, 1953). So the Gricean notion of intention is derivative at best (Gregoromichelaki et al., 2011). Consider how an interlocutor can provide a grammatical context that prompts a speaker to go on expanding their utterance just by fulfilling a pending grammatical dependency:

(5) (a) Jack: I just returned (b) Kathy: from
(c) Jack: Finland. [from (Lerner, 2004)]

Rather than figuring out intentions, what is primitively available in the habitat (whether social or physical) are opportunities for action, *affordances*. Affordances, under our interpretation, trigger motivations for action, either pursuance or avoidance, depending on the nature of the affordance (danger or reward). However, affordances are not simply properties of the environment but relations (Bruineberg et al., 2018) between an agent's niche-related abilities and what the current environment (social or physical) reliably makes available. In our view, this means that the shifting set of affordances in dialogue concerns the collective potential of the interactants, which allows for a negotiated and adjusted conceptualisation of the current situation:

(6) A: so . . . umm this afternoon . . .
B: lets go watch a film
A: yeah

(7) (a) A: I'm pretty sure that **the**:
(b) B: **programmed visits**?
(c) A: programmed visits, yes, I think they'll have been debt inspections. [BNC]

As (Gibson, 2014) suggested, humans and animals perceive the world in terms of affordances rather than in terms of low-level objective features of the environment. This means not only that we do not perceive the world in terms of the categories studied in physics (molecules, atoms, etc.) but also not in terms of individuated descriptive concepts. We extend this view to NLs, assuming that comprehension and production do not

presuppose the "cognitive sandwich" view of perception/action (Hurley, 2008; Gregoromichelaki, 2013). Instead, NLs provide direct access to, or means of intervention in, the conceptual articulation of the sociomaterial human habitat. Consider, for example, how the use of a single accusative-marked DP in Greek characterises an agent's action as incompatible with some selected property of an entity in the visual environment:

(8) [Context: A is contemplating the space under the mirror while re-arranging the furniture and B brings her a chair]
A to B:
tin karekla tis mamas? / #i karekla tis mamas?
the$_{acc}$ chair$_{acc}$ of mum's? / #the$_{nom}$ chair$_{nom}$ of mum's?
(Ise treli?) (Are you crazy?) [Modern Greek]

As the example shows, linguistic and physical actions mesh directly with each other and their interleaving eliminates the need to resort to propositionally or syntactically expansions of non-sentential utterances (NSUs). Generalising, we argue that we perceive our habitat opportunistically in terms of chunks, potential events/actions, triggered by the possible past and future unfoldings of histories of interaction; in this sense, object categorisation independently of the objects' role in potential affordances/constraints of value to the agents is not the usual aim of NL use. If this is the case, the use of words and structures in everyday situations does not automatically imply analysis in terms of semantic representations composed of static propositional elements. Instead, we process both sensory and NL information in an action-predictive manner.

Moreover, unlike the standard view claiming that we decide what to say before specifying how to say it, we argue that NL action selection happens during the continuous micro-interaction with the world/interlocutor, under incomplete awareness of other agents' psychological states and knowledge. As can be seen in the examples earlier (e.g. (6)) and below in (9), we do not need to assume that speakers plan whole propositions or speech acts before they can start speaking. Instead, interlocutors can rely on each other for action completion (6) and are capable through their coordinated activities to locally adjust their language, their relationships, and the environment to current circumstances:

(9) Tess: Okay, so we were not exactly invited. But he's here, and we're here, so that makes us ...
Jack: total idiots!
Tess: in the right place at the right time.

Starting from this perspective, our dynamic approach to NL maintains that what is important for grammar modelling is the time-involving and interactive properties of an NL system while, given data from everyday joint activities, no representational notion of "complete sentence", or even 'syntactic constituent', is required for explaining NL use (Gregoromichelaki et al., 2009b, 2011; Kempson et al., 2016, 2017). In fact, such notions impede natural characterisations of how NL elements contribute to the achievement of agent coordination. As can be seen in (1), (8), it is clear that NSUs are adequate in context to underpin conversational interaction making complete and efficient contributions. As they mesh seamlessly with people's physical activities, public (re)employment and negotiation of the affordances of any NL signal shifts attention towards selected aspects of the current experience (*conceptualisation*) so that various *joint-projects* (Clark, 1996) can be pursued. Such joint-projects (or *language-games* (Eshghi and Lemon, 2014; Eshghi et al., 2017)) can then be advanced just by use of even minimal NL contributions (e.g., *huh?* in (3b)), gestures, eye gaze, and emotional displays without any need to characterise such functional stimuli as in any sense "elliptical" and in need of syntactic/denotational expansion.

Given the methodology of modelling incrementality, any lexical action can be seen, on the one hand, as potentially complete, having effects in its own right but, also, as a trigger for further processing (a *constraint*) by being perceived as embedded within a wider action context. In this way, the local adaptive dynamics of co-action impose an overall structuring in language-games of various scales under which role differentiation and joint responsibility (*action complementarity*) can be induced and sustained without explicit cognitive/public representations of what the agents seek to accomplish. For example, agents – just by assuming incremental processing – can produce, or induce their interlocutor to provide the input required to complete their own actions, thus actualising ad hoc the performance of what have been described as conventional *adjacency pairs* or speech acts (see also earlier, e.g., (5) (Gregoromichelaki et al., 2013):

(10) (a) Psychologist: And you left your husband because ... (b) Client: we had nothing in common anymore

(11) (a) Jane: u:m Professor Worth **said that**, if Miss Pink runs into difficulties, on Monday afternoon, with the standing subcommittee, over the item on Miss Panoff,
(b) Kate: **Miss Panoff?**
(c) Jane: yes, **that Professor Worth would be with Mr Miles all afternoon**, - so she only had to go

round and collect him if she needed him [from (Clark, 1996): 240-241]

As can be seen from all the examples above, given that the grammar is a set of constraints underpinning joint action, any type of syntactic/semantic dependency can be set up and resolved across more than one turn with the resolving element satisfying expectations generated by the utterance of either interlocutor. Moreover, by shifting the focus of NL analysis away from the presumed denotational/referential function of NL strings to their procedural and dynamic potential, we can observe that initiation of what have been characterised as purely syntactic dependencies can operate as ad hoc speech-act indicators, i.e., newly-introduced affordances to prompt the interlocutor to act.

1.4 Syntax/morphology as constraints on affordance fields

Shifting the view of syntax away from representations to a set of procedures complementary to all other actions in dialogue does not mean that we deny its significance. Even though complete sentences/clauses are not necessary in dialogue processing, morphosyntactic constraints are implicated in the incremental continuity of discourse and the choice and licensing of NSUs. For example, in English and other languages, the obligatory binding of a reflexive pronoun can be distributed over turns uttered by distinct interlocutors shifting its form in accordance with contextual parameters that subsententially switch as they track the current speaker/addressee roles (see (2) earlier). Moreover, in morphologically-rich languages, speech acts with subpropositional elements, e.g., requests as in (12) below, and interjections as in (8), require the presence of appropriate 'agreement' morphemes, e.g. case, gender, number, indicating how the uttered "fragment" will induce selection of pertinent affordances from the context created by the utterance:

(12) [Context: A goes into a coffee shop to order coffee]
A to B:
(ena) metrio me gala /
(a-$_{acc-masc-sing}$) medium-$_{acc-masc-sing}$ with milk
#metries me gala
#medium-$_{acc-fem-pl}$ with milk
(A) medium (-sweet coffee) with milk
[request, Modern Greek]

This shows that, rather than inference being required to enrich NSUs to propositional/sentential forms, morphosyntactic constraints play an active role in affordance competition by directing attention to relevant aspects of the situation. For example, the interjection in (8) is very specific with the accusative marking pinpointing the chair as an undergoer of the listener's action while the intonation questions the wisdom of that action. We do not have to assume that some propositional representation needs to be constructed to fit in the "fragment"'s contribution. Such morphosyntactic constraints are not arbitrary, sui generis, and/or parasitic on some primary referential function. Instead, they are used as conceptual resources to differentiate, ad hoc (in (8)), or within more socially established behavioural settings (Heft, 1989) in (12), a salient set of situated affordances regarding the entity involved. Physical and linguistic actions readily compose with each other exactly because they perform meshing contributions in human interaction (Gregoromichelaki, 2017):

(13) She played [PLAYING TUNE ON THE PIANO] not [PLAYING ANOTHER TUNE ON THE PIANO]

(14) OK, let's do it together. So we have [ARM MOVEMENT DEMONSTRATION] and then we go LEG MOVEMENT DEMONSTRATION

1.5 Incremental prediction

Under this view of NL syntax and content, incrementality means, first, that during production, interlocutors do not need to plan whole propositional units before they start speaking. Instead, they need to generate multiple local (probabilistically ranked) predictions of the following perceptual inputs (multimodal stimuli or the other agents' active feedback) for themselves and the interlocutors. This means that they always anticipate how their projected units (words, phrases, or non-NL-actions) will affect the context, which includes the other interlocutors' reactions and changes of their own perceptual stimuli. Through the subsequent process of *affordance competition*, producers then can select a minimal NL action that would ensue as the most rewarding short-term outcome concerning the (joint) task (see Cisek and Kalaska, 2010). This is why speakers can integrate unproblematically gradual modifications of their utterance (e.g. repairs, new interlocutors entering the scene, etc) induced either by themselves (3c) or their interlocutor (4)-(11); and they can go on extending and elaborating either their own utterance (11a) or the one offered by an interlocutor (7c). Thus, the production process is very tightly incrementally coordinated with the interlocutors' responses as they come because it includes a fine-grained incremental feedback loop that controls and procedurally coordinates all participants' actions (Goodwin; Bavelas et al., 2000).

Secondly, during comprehension, in the same way, efficient incremental procedural coordina-

tion demands that addressees also continuously predict the upcoming stimuli and check whether the actions of their interlocutor and actually perceived stimuli conform to those. Thus listeners/perceivers incrementally generate and seek the satisfaction of local predictions, intervening in a timely manner where their anticipations are found in over-threshold error and some "surprising" input cannot be integrated as an unforeseen but adequately rewarding outcome (see, e.g., (6) vs (9)). This local adjustment to task requirements via affordance competition avoids the need to impose the necessary calculation of whole propositional intentions or even implicate (an infinite regress of) mutually known facts. Experimental and empirical conversation analysis (CA) evidence shows that interlocutors do not engage in complex mind-reading processes trying to figure out "speaker meaning", neither do they even need to calculate common ground (Engelhardt et al., 2006, a.o.). The reason for this is that each agent during an interaction does not act independently to realise a predefined action plan, in fact, often, no such plan exists or only emerges post hoc – independently of the agents' explicit goals (hence the value of conversation). As a result, given incremental processing, under the demands imposed by the contingencies of the activity they are engaged in, individuals assume complementary roles locally and opportunistically as they attempt to figure out and direct the conceptualisation of the task itself (Suchman, 1987). To coordinate their perspectives and skills, they engage in orientation actions ("repair"), employing the minimum of resources in order to direct the activity to their predicted reward-affording outcomes (see (11b), (7b)). Moreover, incremental processing affords the option that interlocutors can abandon unfruitful courses of action midway (see (3c)), even within a single proposition, without, nevertheless, presupposing that such productions will be taken as having remained unprocessed:

(15) A: **Bill**$_i$, who ..., sorry, Jill, **he**$_i$'s abroad, she said to let me finalise the purchase.

This leads to a rather different perspective on such "repairs". Even though useful as a descriptive characterisation of normative practices (Schegloff, 2007), singling out a notion of "repair" for explicating the function of such NSUs is misleading from a dynamic modelling perspective: from a dynamic point of view, any behaviour in dialogue is already taken as aiming to control perception (feedback), with perception in turn providing motivation for adjustments and further action. In a sufficiently fine-grained dynamic model, repair as a separate category of constructions (Clark, 1996) turns out to be an artifact of assuming that the interlocutors aim for the establishment of shared common world "representations" employing speech acts that contribute propositional contents (Poesio and Rieser, 2010; Ginzburg, 2012) in the service of reasoning and planning. Instead, we can see the goal of feedback control, striving to integrate 'prediction error' (Clark, 2017a,b), as a constant local aim and structuring factor of any (joint) activities.

These local adaptive dynamics may enable more global organisations with the appearance of a preplanned whole even though NL grammars do not necessarily manipulate overarching notions of "complete sentence", "full proposition" or clearly demarcated speech acts. Various speech acts, potentially implementing 'pushmepullyou' functions (i.e., not differentiated as 'referential'/'descriptive' vs 'directive', Millikan (1995)), can be accomplished while a single proposition is under way with strings, contents, and intentions emerging incrementally without any participant having envisaged in advance the global structure and outcome of the interaction (Gregoromichelaki et al., 2013):

(16) Hester Collyer: It's for me.
Mrs Elton the landlady: **And Mr. Page?**
Hester Collyer: **is not my husband**. But I would rather you continue to think of me as Mrs. Page. [from The Deep Blue Sea (film)]

From the intra-individual psychological point of view, it is the mechanisms of processing NL signals which evoke selective aspects of previous experience of manipulating those signals, while inter-individual feedback leads to the ad hoc creation of temporary inter-individually distributed "grammars" and "conceptual structuring". Thus, concepts, like words, are just the triggers of further action-organising affordances inducing the prediction of further possible outcomes in the form of anticipated feedback from the interlocutor or the environment (see also (Cisek and Kalaska, 2010)). These second-order affordances need to be incrementally reconstructed (enacted) each time. But, with repeated use, conceptual mechanisms, like syntactic (sequence-processing) mechanisms, establish gradually reinforced memory traces that pick up encapsulated easily recoverable nested sensorimotor routines ('macros', i.e., complex constraints). Therefore conceptual mechanisms are also underpinned by the grammar and can be seen as relatively entrenched, culturally-enabled abilities to track culturally or environ-

mentally significant invariances (Millikan, 2005; Casasanto and Lupyan., 2015). Processing words and syntactic structures, like other stimuli, trigger these processes of conceptualisation, and participants in a dialogue need to coordinate on these procedures as well as their physical actions (e.g. turn-taking).

Taken together, these empirical facts show that physical action, syntactic licensing, and conceptual processing are performed incrementally subsententially and in tandem, at each step affording possibilities for further extension by the interlocutors actions or the situational context. Giving due recognition to the foundational nature of dynamic practices of interaction, as we shall now see, we can ground the appearance of presumed phenomena of "conventionalisation", "processing economy" (Kirby, 1999; Carston, 2002) or "signal economy" (Langacker, 1977) – all exemplified by NSUs – in the plastic mechanisms of action coordination rather than burdening inference or representational computation. But this requires viewing NLs as "skills" implemented by domain-general procedures rather than fixed form-meaning mappings. And we now turn to providing a sketch of a procedural grammar architecture whose explicit aim is to directly model such a conception of NLs.

2 Language as action

2.1 Dynamic Syntax

2.1.1 Syntax as state transitions

Dynamic Syntax (DS, Cann et al., 2005; Kempson et al., 2001) is a grammar architecture whose core notion is incremental interpretation of word-sequences (comprehension/perception) or linearisation of contents (production/action) relative to a temporally fine-grained notion of context. The DS syntactic engine, including the lexicon, is underpinned by a specialised version of Propositional Dynamic Logic, which is a language able to express probabilistically licensed transition events among the states of a dynamic system (Sato, 2011). As a result, DS is articulated in terms of conditional and goal-driven actions whose accomplishment either gives rise to expectations of further actions, tests the environment for further contextual input, or leads to abandonment of the current strategy due to its being unviable in view of more competitive alternatives. Words, morphology, and syntax are all modelled as "affordances", i.e., indicators of opportunities for (inter-)action. Such interactions incrementally open up a range of options for the interlocutors so that selected alternatives can be pursued either successfully or unsuccessfully: even though a processing path might look highly favoured initially, due to the changing conditions downstream, it might lead to failure so that processing is aborted and backtracking to an earlier state is required (Sato, 2011). The potential for failure or success relative to goals imbues the activities of the system, even though mainly subpersonal, with a notion of normativity arising from the routinisation of action sequences retrievable as chunks ('macros'). Such macros impose licensed expectations (predictions) that can in turn operate as triggers resulting in nested structures of affordances constraining potential interactions. This normative field of nested anticipations of further interactions built on the basis of prior trial-and-error efforts comes to constitute an instantiation of the *grammar* in particular concrete occasions. Such ad hoc grammars are what prompts or constrains the actions of the individuals participating in a dialogue. Following the opportunities opening up by their recognition of affordances (or avoiding paths that might lead to trouble), interlocutors perform step-by-step a coordinated mapping from perceivable stimuli (phonological strings) to conceptual and physical actions or vice-versa.

To illustrate, we display in Fig 1 the (condensed) steps involved in the parsing of a standard long-distance dependency, *Who hugged Mary?*.[1] The task starts with a set of probabilistically-weighted predicted *interaction-control states* (ICSs) represented in a directed acyclic graph (DAG). At this stage, let's assume the first utterance in a dialogue, the DAG landscape displays all the potential opportunities for parsing or producing relative to the habitat, prompting lexical actions as licensed by the grammar of English. These potential actions are assumed to be "virtually present" for the participants even though they are not all eventually actualised.[2] Either participant might take the initiative to begin the articulation of an utterance while the other is in a state of preparedness checking whether the path pursued by the other interlocutor conforms to their expectations or whether they need to take over and compensate for their lack of coordination (Eshghi et al., 2015). Many alternative processing paths unfold at each step as affordances of the environment and the interlocutor are taken up or are gradually abandoned (see also Sato, 2011; Eshghi et al., 2013; Hough, 2015). A more re-

[1] The detailed justification of DS as a grammar formalism is given elsewhere (Kempson et al., 2001, 2011, 2016, 2017; Eshghi et al., 2011, a.o.).

[2] For relevant notions of "virtual presence", see (Noë, 2012; DeLanda, 2013)

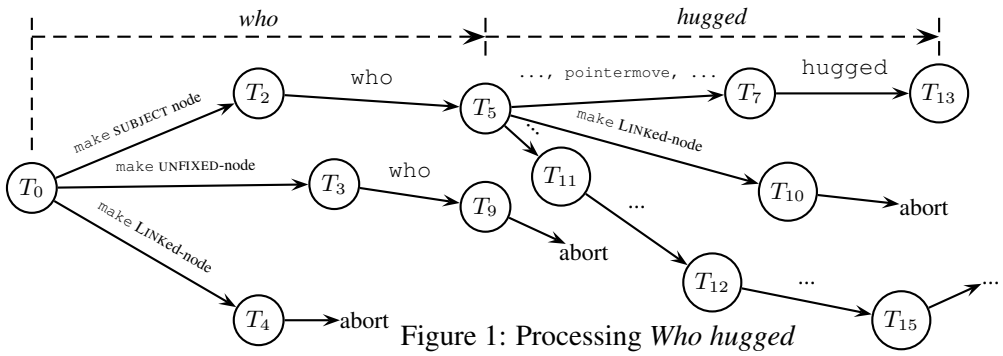
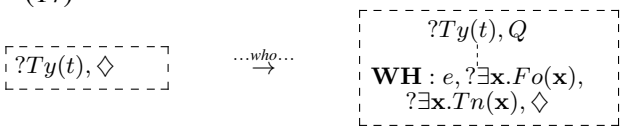


Figure 1: Processing *Who hugged*

alistic graph would also include the possibilities of non-verbal actions, not only gestures, but also physical voluntary actions like, for example, the physical response to a command or request. It is our claim that any "speech act" can be performed non-verbally (see, e.g., (Clark, 2012) and earlier (13)-(14)).

An ICS field tracks the conceptualisation of salient habitat information, implements means of coordination, e.g. "repair" (Eshghi et al., 2015; Howes and Eshghi, 2017), and records the recent and projected history of processing. On this basis, each ICS node contains an indicator of the current focus of attention, the *pointer*, $\Diamond$, which is crucial for the time-linear unfolding of processing as its various positions define distinct potential developments. As far as NL signals are concerned, the pointer is responsible for word-order regularities in any particular language so that processing is constrained with respect to its potential continuations. Since each ICS node includes a pointer position, it will induce a specific cascade of grammatical goals (*requirements*) to build/linearise conceptual structures ('ad-hoc concepts') constrained by what is made available by the macros that constitute the practical knowledge of the language. Each NL imposes a particular conceptualisation of states-of-affairs given what is available in its lexicon and morphological resources. For example, in English, the verb *disappear* only requires a subject whereas the corresponding verb in Greek requires an object as well.[3] Therefore, the conceptualisation affordances in each NL are distinct and the expectations for further perceptual input or action induced at each ICS need to be in accordance with what can be formulated in that NL. For this reason, building language-appropriate conceptualisations is guided in DS by labels characterising ontological types (e for entities in general, e_s for events, $(e \rightarrow (e_s \rightarrow t))$ for one-place predicates ('disappear', in English), $(e \rightarrow (e \rightarrow (e_s \rightarrow t)))$ for two-place predicates ('disappear' in Greek), etc.). In (17) below, focussing now on only one snapshot of an active DAG path in Fig 1 (and only the syntactically-relevant part), we see that the initial goal (indicated by ?), in this case, happens to be realised as a prediction to produce/parse a proposition of type t. Below, on the left, this is shown as a one-node tree with the requirement $?Ty(t)$ and the ICS's current focus of attention, the pointer $\Diamond$:

(17)



Such predictions can be satisfied either through processing a stimulus produced by an interlocutor, by attending to a stimulus from the physical environment or by the agent themselves who can produce the requisite mental or physical actions that fulfil the predicted goal. If linguistic satisfaction of the goal is chosen, either through an interlocutor or the self, as shown in (17), the pointer at a node including a predicted type *t* outcome ($?Ty(t)$) will drive the generation of further predicted affordances/subgoals. In this particular DAG path, preparation needs to be made for accommodating the processing of the lexical stimulus *who* whose affordances are expected to be part of the eventual satisfaction of the current $?Ty(t)$ goal.

In (17), one of the probabilistically highly-favoured next steps for questions in English is displayed in the second partial tree: a prediction that a structurally underspecified node (indicated by the dotted line) can be built and can accommodate the result of parsing/generating *who* along with an indication of interrogative mood (Q). This reflects the fact that for speakers of English, perceiving *who* sentence-initially is constituted by realising affordances of introducing expectations

[3] O Giannis exafanise *(to vaso).
The Giannis disappeared *(the vase).
John caused the vase to disappear.

for a *wh*-question coming up (among other potential). According to DS, realisation of these further affordances for English will be achieved by a combination of executing both lexical and general tree-building action macros that are conditional on certain contextual factors being present (e.g., this being the first word uttered in the sentence) and, in turn, imposing new goals for further processing. For example, given the impoverished nature of case-marking in English, as illustrated here, temporary uncertainty about the eventual contribution of an element like *who* (subject vs object, etc.) is implemented through *structural underspecification* accompanied with an expectation ($?\exists \mathbf{x}.Tn(\mathbf{x})$) that further processing will resolve the uncertainty. Initially so-called "unfixed" tree-nodes model the retention of the contribution of the *wh*-element in a memory buffer until it can be used. Further processing is expected to yield a situation where an argument node is required and no lexical action is provided so that the unfixed node can then be retrieved to satisfy the goal of achieving a licensed tree substructure within the local tree domain. Moreover, grammatical words like *who* and other semantically weak elements (e.g. pronominals, anaphors, auxiliaries, tenses) contribute radically underspecified content in the form of so-called *metavariables* (indicated in bold font), which trigger search ($?\exists \mathbf{x}.Fo(\mathbf{x})$) for their eventual type-compatible substitution from among contextually-salient entities or predicates.

General computational and lexically-triggered macros then intersperse to develop a binary tree: in Fig. (2), the verb *hugged* is next processed. It contributes conceptual structure in the form of unfolding the tree further and assembling an ad-hoc concept (indicated as Hug') developed according to contextual restrictions,[4] It also introduces placeholder metavariables for time and event specifications ($\mathbf{S}_{PAST} : e_s$) whose values need to be supplied by the non-linguistic affordances of the current ICS.

2.1.2 Conceptualisation as state transitions

The conceptual structure being built here is indefinitely extendible (see Cooper, 2012) and "non-reconstructive" in the sense that it is not meant as a passive inner model of the world (see also Clark, 2017a,b) but as a means of interaction with the world via the predictions generated regarding subsequent processing. Accordingly, the affordances that constitute the conceptual structure are viewed as relational (see also Chemero, 2009; Bruineberg et al., 2018): a pairing of (aspects of) the world with a (joint) perspective, namely, those affordances of the sociomaterial world that are accessible relative to the agent(s)' relevant sensorimotor skills shaped by prior experiences and the econiche.[5] Here the perspectival construal of types, as accessible affordances/constraints, is of a more fundamental nature than the notion of *de-se*-type acts in Cooper (forthcomng) in that it permeates the very definition of what an affordance is. It is, therefore, a feature that is constantly present in what agents perceive/achieve. Following standard assumptions in ecological psychology and phenomenology, it is part of the force of an affordance that the perceiving/acting agent becomes aware that they are manipulating the world from a particular point of view. This awareness is enabled as part of the agent's sensorimotor knowledge of regularities and lawful variations regarding the changes in the environment that are caused by the agent's own actions as opposed to actions/events affecting the agent. As a result, when multiple agents are coupled as a temporarily formed agentive system, or in cases where experts use tools or patients use prostheses, the collective perception/action possibilities that emerge for the newly-formed unit are not the result of simple summation of what is possible for the individual components, they can be much more or much less depending on some "enabling" or "disabling" coupling. In both cases, agents are able to perceive this new regime and generally capable to adjust their contributions in complementary ways(Mills and Gregoromichelaki, 2010; Mills, 2014).

The relativisation of the structure of human conceptual types against practice-based abilities has normative implications in that the agent(s) might fail to achieve what is genuinely afforded to them by the sociomaterial environment or the agent(s) might fail to take up the multitude of affordances that have been perceived as potential ("virtual") paths of action. Moreover, given that they engage with real properties of the sociomaterial habitat, the consequences of misapplying their abilities will be detectable by the agents themselves as error signals when their predictions are falsified. Such failure is the source that can lead to re-

[4] In (Purver et al., 2010), this is modelled as a *record type* via a mapping onto a Type Theory with Records formulation, but we suppress these details here: see (Purver et al., 2011; Eshghi et al., 2013; Hough, 2015; Hough and Purver, 2014; Gregoromichelaki, 2017; Gregoromichelaki and Kempson, 2018).

[5] In this actionist and externalist perspective, we diverge from standard construals of TTR as in (Ginzburg, 2012),Cooper, forthcomng.

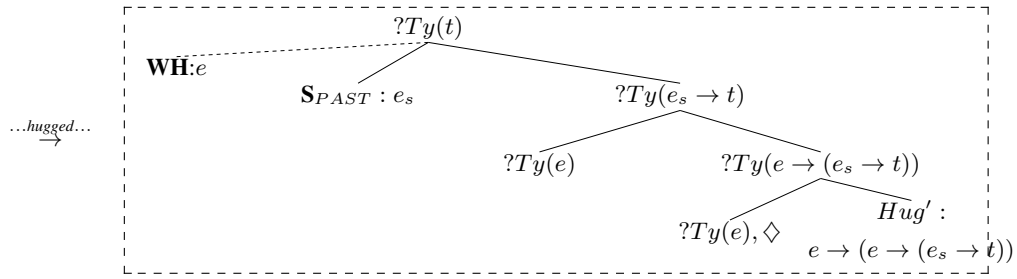


Figure 2: Processing *hugged*

pair and adjustment so that long-term learning and adaptation are the outcomes. Given the requisite dynamicity and world grounding, semantic types, like Hug' here, stand as abbreviations of the outcomes of complex conceptual abilities, either personal or subpersonal, that deliver embedded DAG structures of nested affordances. Such type labels then constitute additional ICS choice points in the generation of further potential paths actions within the DAG. Given this conception, what individuates types is their differentiation according to the provision of sets of available actions realisable in the next steps within the affordances field. Since we take perception and NL-comprehension as a time-extended and incremental activity, the manifestation or awareness of a concept will develop gradually rather than instantaneously in an act of judgement. To take a "syntactic" example, type t is differentiated from type $(e_s \rightarrow t)$ in that the former (minimally) leads to the prediction of a left daughter of type e_s and a right daughter of type $(e_s \rightarrow t)$ whereas the latter leads to the prediction of e and $(e \rightarrow (e_s \rightarrow t))$. This is what differentiates these types, not their labels, which are just test conditions in the conditional procedures that implement the operation of grammatical and extra-linguistic actions. Similarly, we take the conceptual type Hug' as initially appearing in the form of a requirement in the DAG ($?Hug'$), thus generating nested structures of potential actions regarding aspects of interaction with an event of hugging, some of which will be taken up and others abandoned. As such, the types (concepts) are mainly constituted by subpersonal mechanisms, however, the results of their operation can be brought to consciousness by processes of reification for purposes of, e.g., linguistic negotiation, explicit planning, theory construction, or teaching.

Given affordance competition, agents select their next actions based on possibilities (probabilistically) grounded on these types which function as 'outcome indicators' ((Bickhard and Richie, 1983b)) so that the predictions yielded by these types might be reinforced (verified) or abandoned (fail) in the next steps. As long as they remain as live possibilities, the operations of the types will keep triggering flows of predictions for further (mental or physical) action even if particular paths of sequences of nested predictions are not taken up. Maintaining even abandoned options is required for the explicit modelling of conversational phenomena like clarification, self/other-corrections, etc. but also, quotation, code-switching, humorous effects and puns (Hough, 2015; Gregoromichelaki, 2017):

(18) John went swimming with Mary, um. . . , or rather, surfing, yesterday.
['John went surfing with Mary yesterday']

(19) The restaurant said it served meals any time so I ordered breakfast during the Renaissance. [Stephen Wright joke]

So, the contribution of the verb *hug* to the DAG would be a conceptual type here just labelled as Hug' to encompass the set of relevant affordances that are predicted as potential further engagements with an event of hugging. As part of its "syntactic" contribution, which we do not consider as qualitatively distinct given what we discussed earlier with respect to *disappear* in Greek and English, *hug* will also introduce the prediction of an upcoming invocation of an entity that undergoes the hugging action. This is implemented by the construction of a new node on the tree in order to accommodate this predicted occurrence. Now returning to the processing stage displayed in Fig (2), we see that the pointer $\Diamond$ is residing at this predicted argument node ($?Ty(e)$). This implements the word-order restriction in English that the object needs to follow the verb. In languages with explicit morphological case, like Greek as seen in (8), (12) earlier, it will be the inevitable case morphology instead that induces the conceptualisation of the noun content under a particular role assignment in some event conceptualisation triggered by a verb or the physical situation. For this reason, DPs in Greek can appear in a variety of positions in the

sentence and they place much less requirements for contextual support than in English where the thematic role is not immediately predictable.

Returning to English now, at the stage shown in Fig. (2), the word *Mary* can be processed to initiate the tracking of a contextually-identifiable individual ($Mary'$) at the argument node internal to the predicate.[6] After this step, everything is in place for the structural underspecification to be resolved, namely, the node annotated by *who* can now unify with the subject node of the predicate. The presence of the metavariable on this node eventually results in an ICS that includes the provision of a value for the metavariable, in effect an answer to the question posed by the utterance of *Who hugged Mary?*, imposed as a goal ($?Q_{\mathbf{WH}}$) for the next action steps (to be resolved either by the speaker or the hearer), see Fig. 2.1.2

2.1.3 Coordinating comprehension-production

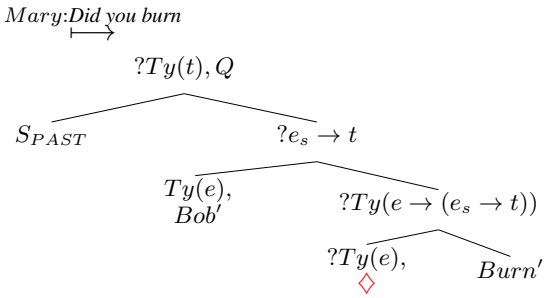
The DS model assumes tight interlinking of NL perception and action: the predictions generating the sequence of trees above are equally deployed in comprehension and production. *Comprehension* involves the generation of predictions/goals and awaiting input to satisfy them. *Production* equally involves the generation of predictions/goals but, this time, also the deployment of action (verbalising) by the predictor themselves in order to accomplish their predicted goals. By imposing top-down predictive and goal-directed processing at all comprehension/production stages, interlocutor feedback or changing of direction due to perceiving one's own action consequences ('monitoring') is constantly anticipated and seamlessly integrated in the ICS (Gargett et al., 2008, 2009; Gregoromichelaki et al., 2009a; Purver et al., 2010; Eshghi et al., 2015). Feedback can extend some particular ICS either via linking simple proposition-like structures (such as in (1), (3c), (7c), (11c), (14)), or, more locally, by attaching linked elaborations of nodes of any type (e.g. adjunct processing, see (11a)). Given the modelling of word-by-word incrementality, at any point, either interlocutor can take over to realise the currently predicted goals in the ICS. This can be illustrated in the sharing of the dependency constrained by the locality definitive of reflexive anaphors:

(20) Mary: Did you burn Bob: myself? No.

[6]For the view that such entity concepts are tracking abilities allowing the accumulation of knowledge about individuals, see (Millikan, 2000)).

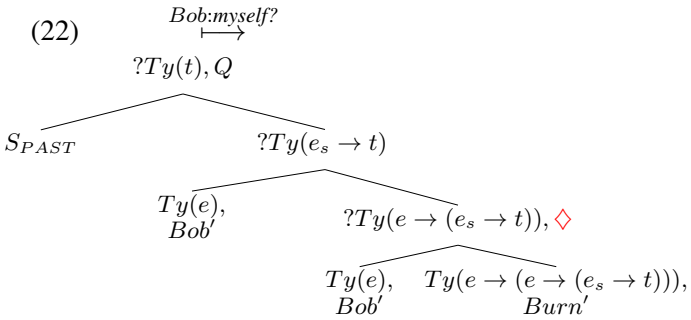
As shown in (20), Mary starts a query involving an indexical metavariable contributed by *you* that is resolved by reference to the $Hearer$ contextual parameter currently occupied by Bob.

(21)



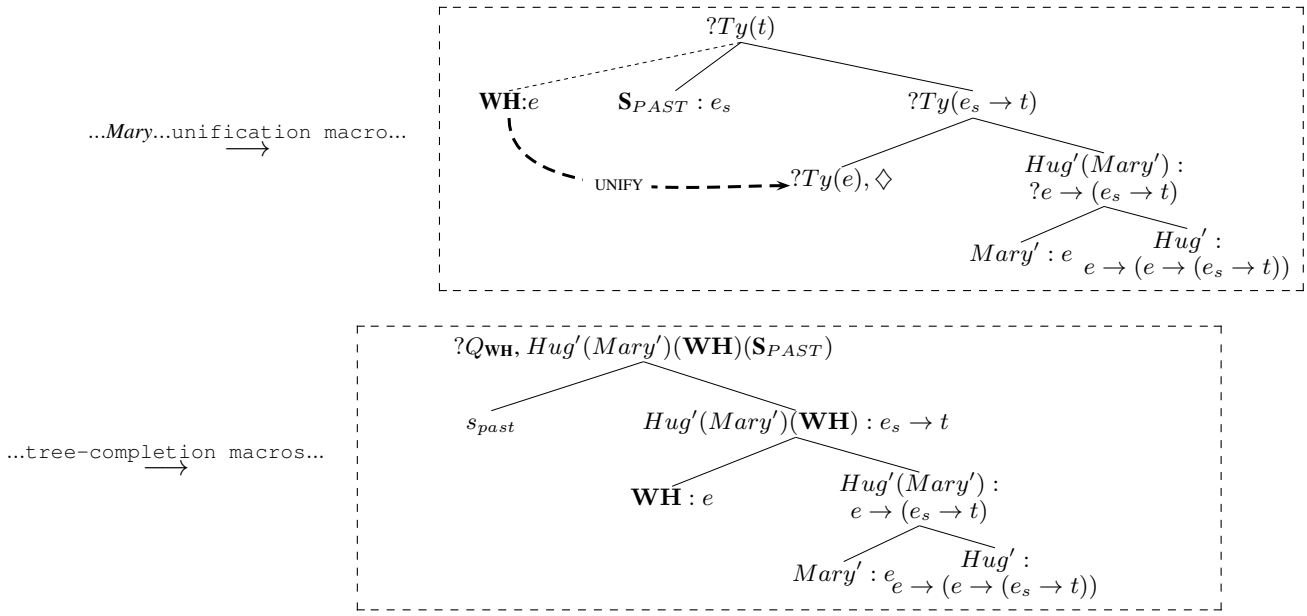
With the ICS tracking the speaker/hearer roles as they shift subsententially, these roles are reset in the next step when Bob takes over the utterance. *Myself* is then uttered. Being a pronominal, it contributes a metavariable and, being a reflexive indexical, it imposes the restriction that the entity to substitute that metavariable needs to be a co-argument that bears the $Speaker$ role. At this point in time, the only such available entity in context is again Bob which is duly selected as the substituent of the metavariable:

(22)



As a result, binding of the reflexive is semantically appropriate, and locality is respected even though joining the string as a single sentence would be ungrammatical according to any other syntactic/semantic framework.This successful result relies on (a) the lack of a syntactic level of representation, and (b) the subsentential licensing of contextual dependencies. In combination, these design features render the fact that the utterance constitutes a joint action irrelevant for the well-formedness of the sequence of actions constituting the string production.

This means that coordination among interlocutors here can be seen, not as propositional inferential activity, but as the outcome of the fact that the grammar consists of a set of licensed complementary actions that a speaker-hearer temporary agentive unit performs in synchrony (Gregoromichelaki et al., 2011; Gregoromichelaki,



2013; Gregoromichelaki and Kempson, 2016) within a space of joint affordances.Given that parsing/production are joint predictive activities, driven by the participants' joint possible affordances, a current goal choice point in the DAG may be satisfied by a current hearer, so that it yields the retrieval/provision of conceptual information that matches satisfactorily the original speaker's needs or preferences, as in (7), (5), deflects the original speaker's action, (4), or can be judged to require some adjustment via backtracking that can be seamlessly and immediately provided by feedback extending/modifying the ensuing ICS, (3e), (15).

3 Conclusion

The dynamic articulation of DS, and its emphasis on incrementality and domain-generality of processing mechanisms, reflect the formalism's cross-modal applicability via a fundamental property of action: goal-directed predictivity. This allows for parsimonious explanations of NL data and accommodates now standard psycholinguistic evidence of prediction from sentence processing studies (Altmann and Kamide, 1999; Trueswell and Tanenhaus, 2005, a.o.). Crucially, DS as a formalism is currently designed to also model experimental data from multimodal, situated dialogue where notions of know-how, agent coupling, joint purpose, and direct perception replace the need for propositional inferential theories and the necessity of planning. Gricean theories of common ground place a heavy burden on mindreading capacities as they separate syntactic and semantic knowledge from action and perception. This is because, standardly, they are articulated from an internalist and individualistic perspective, assume separate stages of perceptual processing, cognitive elaboration, and action execution, and do not acknowledge the importance of offloading inferential activity to the interactive exploration of the sociocultural and material environment. DS processing in contrast is able to take advantage of the temporally extended nature of such explorations at various scales because it assumes that know-how of grammar and practice-conforming behaviour can be uniformly formulated as meshing constraints available to the interlocutors. Moreover, DS does not assume that perception/action and grammar are linked only via the mediation of processing/inferring sentential/propositional units. Accordingly, there is no notion of wellformedness defined over sentence-proposition mappings, only systematicity/productivity of incremental, interaction-oriented NL procedures constrained by, and constraining in turn, affordances available in the sociomaterial environment. For this reason, NL procedures can be modelled as interleaving seamlessly with physical actions and multimodal sources of information.

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