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Agreement groups circuits for a unified account of syntactic priming: Theory and applications

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Abstract

The present paper seeks to highlight qualitative congruencies between empirical data from behavioural experiments on linguistic structural priming and insights obtained from the Agreement Groups (AG) approach, a cognitive, usage-based, distributional framework for modelling linguistic processing. Specifically, we demonstrate that a wide variety of experimental observations can be given theoretically consistent interpretation when the AG model is situated in a cognitive circuitry-architecture of nodes and connections. With the AG method, structural priming naturally emerges as a consequence of structural similarity via repeated activation of basic structural units, i.e. AGs. The analysed phenomena include structural priming of particular linguistic constructions, lexical/semantic facilitation (boost), cross-linguistic priming, anomalous utterances, and developmental aspects of structural priming. We also point out experimentally testable issues that come up along the hypothetical discussions.

Keywords: cognitive modelling, linguistics, syntax, structural priming, language acquisition

1. Introduction

Syntactic or structural priming became an important notion of psycholinguistic research after the classic experiments of Bock (1986) demonstrated that participants were more likely to use passive sentences in a picture description task if they had been repeating passive sentences previously. Abstract structural priming has been shown to be at work behind a wide variety of linguistic phenomena ever since (see e.g. Pickering and Ferreira, 2008, or Branigan and Pickering, 2017, for an overview). Scrutinising findings on syntactic priming in production and comprehension, and on bidirectional priming between comprehension and production, Branigan, Pickering, Liversedge, Stewart, and Urbach (1995) emphasise that results from priming experiments may tap into linguistic knowledge, specifically, into mental representations of linguistic structures. This point is taken further in Branigan and Pickering (2017) where the authors argue that structural priming experiments provide a behavioural measure for the direct examination of cognitive representations underlying language use.

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The existing mainstream approaches to priming phenomena differ widely with respect to representational assumptions. In activation-based models (e.g. Pickering and Branigan, 1999) priming is a consequence of residual activation of network nodes. Syntactic structures are retrieved by spreading activation, and repeated retrieval of syntactic structures is facilitated by residual activation. Error-driven models (e.g. Chang et al., 2006) interpret syntactic priming as a result of violated expectations. If an encountered syntactic structure violates the listener's expectation, the error is corrected by adjusting neural weights so that the unexpected structure will have higher probability. In an exemplar-based approach (e.g. Ambridge, 2020) priming occurs because the exemplars previously activated for a given utterance will facilitate the retrieval of a similar utterance with a similar structure. Although all models offer explanations for repetitive usage of linguistic structure, problematic issues remain. Jacobs et al.'s (2019) experiments, for instance, reveal that while activation models are consistent with self-priming, they cannot account for the inverse frequency effect, and that while error-driven models are consistent with the inverse frequency effect, they cannot account for self-priming. Messenger et al. (2020) claim that the inverse frequency effect and short-lived lexical boost vs. long-lived abstract priming cannot be fully explained by a radical exemplar-based model. The basic assumptions of the model we propose here may be reminiscent of the favourable properties of the abovementioned approaches. *Agreement Groups* (AGs) are, by definition, exemplar-based. The circuitry architecture representation of AGs allows for activation-based argumentation as in the activation-based models and also allows for employing notions like connections between nodes and connection strength, ultimately enabling representational adjustments for error-driven approaches.

The idea of *agreement groups* and *agreement groups coverage* was presented in a series of works as a distributional approach to modelling linguistic processing. Drienkó (2014) showed that AGs, i.e. groups of 2-5 word long utterances differing from a base utterance in only one word, can account for a certain percent of novel utterances of English mother-child speech, may facilitate categorisation (lexical/syntactic, semantic), and might serve as a basis for "real" agreement relations. The findings were confirmed cross-linguistically by Hungarian and Spanish data in Drienkó (2013a). For the processing of longer utterances the notion of *coverage* was introduced in Drienkó (2013b, 2013c, 2015, 2016b). The coverage apparatus seeks to identify 2-5 word long fragments of an input utterance and map them onto AGs. By applying the AG coverage method to mother-child speech (Anne sessions, Manchester corpus: Theakston et al., 2001) from the CHILDES corpora (MacWhinney, 2000), it was found that the continuous and the discontinuous cases yielded, respectively, 78% and 83% average coverage values.

The AG model assumes two basic levels of linguistic processing. The first level corresponds to direct mappings onto AGs for processing holophrases, shorter utterances, or "formulaic" expressions. The second level requires more computational effort since firstly AG-compatible fragments have to be found (Level 1 mappings), then an optimal combination of fragments must be selected in order to assign a grammatical *coverage structure* (CS) to the utterance being processed. The inherent dualistic properties of the AG framework are discussed in Drienkó (2020b) along with contact points for research on cognitive linguistic processing including generalisation, categorisation, a semantic/syntactic categorical interpretation of the *less-is-more* principle of Newport (1990) and its relationship to U-shaped learning (Strauss, 1982) and vocabulary spurt (e.g. Ganger and Brent, 2004), parallelisms with the dual-process model of Van Lancker Sidtis (2009), lateralization of formulaic and analytical speech (e.g. Sidtis, Sidtis, Dhawan, and Eidelberg, 2018), neurolinguistic processing (Bahlmann and Friederici, 2006), and the processing of complex linguistic structures such as long-distance dependencies, crossing dependencies, or embeddings (cf. also Drienkó, 2016b). For a more comprehensive model, Drienkó (2020c, 2024b) combined the AG framework with the Largest Chunk algorithm (Drienkó, 2016a, 2018) to produce AG systems with groups consisting of text fragments obtained from automatically segmented word sequences.

The present study seeks to demonstrate that experimental results are congruent with a model where the cognitive representation of linguistic knowledge is based on appropriate groupings of similar linguistic material. In particular, we propose the AG model, especially as situated in a network of nodes and connections, as a theoretical framework wherein a wide variety of structural (even semantic) priming phenomena can be interpreted straightforwardly.[2]

The discussion will be hypothetical in nature since we will assume the existence of possible AGs underlying the processing of particular linguistic phenomena without, naturally, there being any direct evidence that such, or exactly those, AGs exist. However, by assuming them we can provide a "constructive" account of the cognitive underpinnings of the mechanisms potentially responsible for linguistic processing. Congruency with experimental data, then, can justify our claim that for any experimental phenomenon discussed here, in principle, there can exist a corresponding configuration of AGs on which a theoretical account can be grounded. Furthermore, no any two learners of any language can be exposed to exactly the same linguistic input, which means that no two AG-bases for any two speakers can be expected to be identical. Then, arguably, even if the exact collection of AGs were known for one speaker, it could not automatically yield valid conclusions for the linguistic behaviour of another speaker. Incorporating this fact into our expectations, we will wish to demonstrate that for any average, healthy speaker there can exist some AG configurations that can account for the experimental data. In other words, our results will be immediately valid for only a subset of English. However, this subset, we intuit,

[2]Some confluence of structural priming findings and the AG model was reported as:
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Drienkó, L. (2024a). Exemplar-based Agreement Groups for linguistic abstractions: the emergence of syntactic priming effects. Talk presented at the *Linguistics Beyond and Within (LingBaW) Conference*, KUL Lublin, Poland, 17-18 October, 2024.

might grow arbitrarily large and approach the English language itself. Thus, although we do not report numerical results directly, the empirical aspects of our approach stem from the experimental foundations of the AG framework, on the one hand, and of structural priming research, on the other.

The layout of this study adopts the following order. The rest of this introduction is dedicated to a brief familiarisation with the basic components of the AG framework. Section 2 illustrates how structural priming phenomena can be analysed within this framework relying on the notion of structural similarity. Section 3 presents a circuitry interpretation of the AG model and discusses general priming-related issues whose analyses specifically favour such an AG-circuit setting (viz. semantic/lexical boost, cross-linguistic priming, and temporal characteristics of priming effects: short-lived lexical facilitation vs. long-lived structural priming). Section 4 provides AG analyses for some "classic" findings in structural priming research concerning particular linguistic constructions. Section 5 shows how anomalous utterances can be processed with the help of a reconstruction component of the AG model. Section 6 relates the U-shaped developmental dynamics of the AG space to observations in developmental studies. Section 7 draws some conclusions, points to experimentally testable issues, and outlines some future research directions.

1.1. Overview of the Agreement Groups model

1.1.1. Agreement Groups

The basic cognitive underpinning of the AG model lies in forming groups of utterances differing in only one word from a given "base" utterance. Actually, each utterance of a training corpus has its own group and, consequently, is a base utterance of its own group. For instance, the training corpus (1) yields the AGs under (2).

(1)

mommy drinks	daddy drinks	baby drinks	mommy wants
drinks tea	drinks milk	wants tea	by baby
tea is drunk	milk is drunk	tea is wanted	
goat milk	cow milk	by daddy	

(2)

AG1	AG2	AG3	AG4
<u>mommy drinks</u>	<u>daddy drinks</u>	<u>baby drinks</u>	<u>mommy wants</u>
daddy drinks	mommy drinks	mommy drinks	mommy drinks
baby drinks	baby drinks	daddy drinks	
mommy wants			
AG5	AG6	AG7	
<u>drinks tea</u>	<u>drinks milk</u>	<u>wants tea</u>	
drinks milk	drinks tea	drinks tea	
wants tea			
AG8	AG9	AG10	
<u>tea is drunk</u>	<u>milk is drunk</u>	<u>tea is wanted</u>	
milk is drunk	tea is drunk	tea is drunk	
tea is wanted			
AG11	AG12	AG13	AG14
<u>goat milk</u>	<u>cow milk</u>	<u>by daddy</u>	<u>by baby</u>
cow milk	goat milk	by baby	by daddy

Formally, an AG can be represented as a hypothetical table for concatenating linguistic units, where columns in the table symbolise (agreement) categories, and any element (word) in a column can be concatenated with any other in the next column, cf. Table 1. We say that an utterance is compatible with an AG, i.e. can be mapped onto that AG, if it can be obtained by choosing words from the subsequent columns of the corresponding hypothetical table and the number of words in the utterance equals the number of columns (i.e. utterance positions) in the AG. In fact, AGs are basic processing units for both familiar (viz. utterances in the training corpus) and novel linguistic sequences. For instance, AG1 licenses novel utterances *daddy wants* and *baby wants* besides the group member utterances *mommy drinks, daddy drinks, baby drinks,* and *mommy wants.*

Table 1
Tabular representation for AG1

hypothetical table for AG1	
mommy	drinks
daddy	wants
baby	

1.1.2. Combination of groups, coverage structure

Recall that utterance length is arbitrarily restricted to five words in AGs. For utterances longer than five words the model activates a *coverage* mechanism for building the *coverage structure* (CS) of any utterance. The coverage structure of an utterance is a tabular visualisation of a configuration of AGs onto which fragments of the utterance in question can be mapped. For instance, Table 2 shows the possible fragments that can cover sentence *daddy wants milk*. Fragment *daddy wants* can be mapped onto AG1 while *wants milk* onto AG5.

Table 2
CS for 'daddy wants milk'

daddy	*wants*	*milk*	
daddy	wants		AG1
	wants	milk	AG5

Numerically, coverage can be less than 100% when not all positions in a target utterance can be covered by appropriate (i.e. AG-mappable) fragments. For example, *mommy wants soup* would result in a 2/3≈67% coverage value since the third utterance position could not be covered because fragment *wants soup* cannot be mapped onto any AG in (2), cf. Table 3.

Table 3
Incomplete coverage (<100%)

mommy	*wants*	*soup*	
mommy	wants		AG1, AG4
	wants	?	AG ?

AGs can be represented discontinuously in CSs. For instance, AG5 corresponding to fragment *wants milk* in utterance *daddy wants goat milk* is represented discontinuously in Table 4 owing to the word *goat* as inserted between *wants* and *milk*. Discontinuous mapping in the AG framework is computationally more complex. The extra complexity in the discontinuous case is due to the fact that the mapping algorithm considers the collection of all possible discontinuous fragments in the input utterance as opposed to the collection of all possible continuous fragments in the continuous case. Generally, the latter collection is much smaller.[3]

Table 4
Discontinuous coverage: AG5 covers fragment 'wants milk' discontinuously

daddy	*wants*	*goat*	*milk*	
daddy	wants			AG1
	wants		**milk**	AG5
		goat	milk	AG11/AG12

An important question concerning the grammaticality of utterances is which AGs can be combined with which others in a given CS for a grammatically correct utterance. In order to be able to explicitly model the combinability of AGs, we can employ the notion of *Combinability Constraints* (CC). CCs are "atomistic" CSs constituting elementary patterns of how words in, basically, two AGs can be combined. The CS, e.g., for *daddy wants milk* in Table 2 can also be regarded as CC(1,5), i.e. a combinability constraint prescribing how AG1 and AG5 can be combined, namely, that the word mapped onto the second word position of AG1 must be mapped onto the first position in AG5. A combinability pattern for more than two AGs can more conveniently be interpreted as a memorised CS, or *schema***,** in the AG framework.

Note that fragments represented by AGs in CSs do not necessarily coincide with phrase-structure constituents. However, in the event of a suitable constellation of AGs in a particular CS, it can be possible to extract or derive a quasi "constituent structure" for the utterance in question. This structure will be void of mother-daughter relations, though, since CSs per se do not intrinsically impose hierarchies on AGs. We sketch a possible derivation for *daddy wants goat milk* as (3).

(3)
goat milk → (goat milk $_{\text{AG11/AG12}}$) →
wants (goat milk $_{\text{AG11/AG12}}$) →
(wants (goat milk $_{\text{AG11/AG12}}$) $_{\text{AG5+AG11/AG12}}$) →
daddy (wants (goat milk $_{\text{AG11/AG12}}$) $_{\text{AG5+AG11/AG12}}$) →
(daddy (wants (goat milk $_{\text{AG11/AG12}}$) $_{\text{AG5+AG11/AG12}}$) $_{\text{AG1+AG5+AG11/AG12}}$)

[3] In the circuitry setting to be discussed later, the larger mapping complexity for discontinuous fragments might be ascribed to memory processes: e.g. it may be necessary to suspend mapping onto one AG when an intervening fragment requires starting mapping onto another. Then the processing status of the first AG should be allocated some extra memory while the processing of the second is going on. Cf. Section 3.

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1.1.3. Developmental aspects of AGs: Homogenisation of groups

Depending on the distribution of linguistic elements in the training corpus, AGs can be rather "inhomogeneous". In (4), for example, the *the boy* group includes the adjective '*big'* along with the definite article '*the'* and the indefinite '*a'*. Although the AG yields grammatically correct novel utterances (viz. *a girl, big girl, a car* and *big car*) it can be desirable to have groups with grammatically more coherent or homogeneous utterances. Therefore, the AG framework assumes an error-correcting or *homogenising* mechanism that can reorganise groups by, primarily, removing utterances. By removing e.g. *big boy* from (4) the resultant AG represents a determiner-noun word combination. Thus, integrating information on lexical-syntactic categories into the mapping-system results in modifications of the AG space (Drienkó, 2017). Semantic information can likewise affect the shaping of AGs (Drienkó, 2020a). Removing *the car* from the example in (4) results in a group with only animate nouns.

(4)

<u>the boy</u>
a boy
big boy
the girl
the car

Developmentally, the *homogenisation* process dictates a U-shaped trajectory (e.g. Strauss, 1982) since the appearance of either syntactic or semantic category information at some point during the formation of the processing system causes an initial drop in syntactic processing capacities (due to a reduction in average group size). However, with increasing training corpus size, i.e. with a growing body of memorised utterances, processing capacities improve (cf. also Drienkó, 2020b, Section 4.5).

1.1.4. Category assignment

Columns in the hypothetical table representations of AGs are regarded as *agreement categories* in our model. For instance, the first words in the utterances of AG1 are assigned agreement category AG1_1, or the words in the second column belong to category AG1_2, cf. (5). Agreement categories may facilitate the development of higher-level categories, or "metacategories". Having already realised that certain words of an agreement category belong to a particular higher-level category, the language learner may infer that other words in the same agreement category also belong to that higher-level category. Knowing that e.g. '*mommy*' refers to a human being, a learner might extend this humanness feature to the other members of AG1__1, viz. *daddy* and *baby*. Category assignment may also be facilitated by characteristic or prototypical words. Including e.g. *who drinks* in AG1 could prompt the language learner to realise that category AG1_1 might actually represent words referring to human entities belonging to a higher-level category, say C_{WHO}, symbolised by the question word '*who'*, cf. (6). (cf. also Drienkó 2020b, Sections 4.1, 4.2).

(5)

AG1
<u>mommy drinks</u>
daddy drinks
baby drinks
mommy wants

hypothetical table for AG1	
mommy	drinks
daddy	wants
baby	
↑ Category: AG1_1	↑ Category: AG1_2

(6)

AG1
<u>mommy drinks</u>
daddy drinks
baby drinks
mommy wants
who drinks

hypothetical table for AG1	
mommy	drinks
daddy	wants
baby	
who	
↑ Category: AG1_1	↑ Category: AG1_2

AG1_1 → C_{WHO}

1.1.5. Concepts over AGs

It is possible to add an explicit semantic component to the AG framework by defining semantic concepts over AGs. Agreement categories, i.e. columns in the tabular representations of AGs can be interpreted as positional attributes and the actual words in an agreement category as the possible values for the positional attribute in question. The most generic concept is the one with all possible attribute values permitted. Amongst the examples of (7), the most generic concept is *'What all do or can/could do'*, symbolised as (MOMMY ∨ DADDY ∨ BABY) ∧ (DRINKS ∨ WANTS), subsuming all the six utterances that are mappable onto AG1. The least generic, or most specific, concepts are those with only one legal value for each attribute, corresponding to individual utterances that can be mapped onto AGs. Utterance *daddy drinks*, for example, can be understood as representing the concept *'What daddy does'* in the context of AG1 describable formally as DADDY ∧ DRINKS. The concept MOMMY ∧ (DRINKS ∨ WANTS), *'What mommy does'*, represents the two utterances of AG1 *mommy drinks* and *mommy wants* whereas DADDY ∧ (DRINKS ∨ WANTS) should rather be understood as *'What daddy does or can/could do'* since while *daddy drinks* is explicitly stated in the group, *daddy wants* requires a kind of "analogical inference" (cf. also Drienkó, 2020b, Sections 5.2 and 5.3).

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(7)

AG1 mommy drinks daddy drinks baby drinks mommy wants	Positional attribute values AG_1: MOMMY, DADDY, BABY AG_2: DRINKS, WANTS

Example concepts
'What all do or can/could do': (MOMMY ∨ DADDY ∨ BABY) ∧ (DRINKS ∨ WANTS)
'What daddy does': DADDY ∧ DRINKS
'What mommy does': MOMMY ∧ (DRINKS ∨ WANTS)
'What daddy does or can/could do': DADDY ∧ (DRINKS ∨ WANTS)

2. Priming in the AG model

The AG model was primarily designed for modelling linguistic processing of individual utterances. Also, it intrinsically had a developmental aspect due to the temporal dynamics of the expansion of the AG space ("learning"). However, no specific attention was paid to how the processing of one utterance can affect the processing of another. AGs were supposed to be available on demand, whenever needed. Nevertheless, AGs can also be regarded as abstract mapping units or patterns that can be activated repeatedly, and whose activation on one occasion can affect their repeated activation. It could make sense both computationally and cognitively, for instance, that recently activated AGs can be found faster for a matching utterance. In modelling priming, we will adopt this picture of repeatedly usable AGs whose previous activation affects the processing of subsequent utterances.

As a first example, consider the sentence *mommy drinks tea*. Since the utterance involves mapping onto groups AG1–AG7, i.e. "activates" these groups, they readily offer themselves for mapping for subsequent utterances. On encountering e.g. *daddy wants milk,* it may become easier for the mapping system to select the previously activated AGs that are compatible with the current utterance. Indeed, the coverage structure (CS) of *daddy wants milk* consists of a subset (AG1 and AG5) of the AGs compatible with *mommy drinks tea*, cf. Table 5 and Table 2 repeated as Table 6. Thus we might say that utterance *mommy drinks tea* can "prime" the subsequent *daddy wants milk.*

Table 5
Coverage structure for 'mommy drinks tea'

mommy	*drinks*	*tea*	
mommy	drinks		AG1,AG2,AG3,AG4
	drinks	tea	AG5,AG6,AG7

Table 6 (Table 2)
Coverage structure for 'daddy wants milk'

daddy	*wants*	*milk*	
daddy	wants		AG1
	wants	milk	AG5

On the other hand, a passive utterance is likely to involve different AGs. For instance, *milk is wanted by daddy*, instead of *daddy wants milk*, requires AG8, and AG13 or AG14, none of which is included in Table 5. Thus the CS for *milk is wanted by daddy* is not facilitated, or primed, by *mommy drinks tea*, cf. Table 7.

Table 7
Coverage structure for 'milk is wanted by daddy '

milk	*is*	*wanted*	*by*	*daddy*	
milk	is	wanted			AG8
			by	daddy	AG13/AG14

Such kind of dissociation between the processing of active versus passive sentences in priming experiments was famously reported in Bock (1986). For another introductory example let us consider findings from Chang, Bock, and Goldberg (2003) who report priming effects for sentences with the same syntactic constituent order (viz. NP V NP PP) but different thematic role order. Sentences with theme-location order primed theme-location targets, e.g. *The man sprayed water on the wall*, whereas location-theme primes facilitated location-theme targets, e.g. *The man sprayed the wall with water.* One possible AG account of the experimental findings can be based on properly homogenised groups (cf. 1.1.3). The formation of AGs with verbs whose meaning may be connected to '*transferring some (soft/ liquid) substance (theme) onto the surface of some object (location)*' and nouns denoting either substances or objects in their proper categories (positions) along with concomitant prepositions can facilitate the observed dissociation in thematic role mapping. For instance, the utterance *smeared paint on door* from the theme-location AG_{TL1} under (8) could prime *sprayed water on wall* whilst *cleaned car with water* from the location-theme AG_{LT} can facilitate *sprayed wall with water*. Note that an utterance/fragment can be mapped onto several AGs so it could also be possible that priming is collectively affected by all the AGs that a given utterance is compatible with. As *smeared paint on door* can also be mapped onto AG_{TL2} under (8) it could also prime theme-location targets that are not mappable onto AG_{TL1} but are mappable onto AG_{TL2}, e.g. *splattered oil on table*.

(8)

AG_{TL1}	AG_{TL2}	AG_{LT}
<u>sprayed water on wall</u>	<u>smeared oil on paper</u>	<u>sprayed wall with water</u>
sprayed paint on wall	smeared oil on table	sprayed wall with paint
sprayed water on door	smeared paint on paper	sprayed car with water
sprinkled water on wall	splattered oil on paper	sprinkled wall with water
smeared water on wall	smeared oil on door	cleaned wall with water
…	…	…

Note that for structural priming to occur it is not absolutely necessary that prime and target share exactly the same structure, or even the same number of words. Accordingly, we see structural priming to reflect the degree of structural similarity between the utterances involved. Utterance *mommy drinks tea*, for instance could also prime *daddy wants goat milk*, along with *daddy wants milk*, because the respective CSs all include AG1 and AG5, cf. Tables 2 (6), 4, and 5. In a sense, however, the CS for *daddy wants milk* is more similar to the CS for *mommy drinks tea* since both utterances involve the same number of words, three, and neither requires discontinuous mapping onto AG5 while *daddy wants goat milk* does.

3. AGs in a circuitry architecture

In this section we outline how AG processing could be performed in the neural circuitry system of human cognition by situating the AG model in a network-like architecture of excitable nodes with connections. Such a picture of cognitive processing may be reminiscent of spread-activation models like, e.g., Levelt, Roelofs, and Meyer (1999) or, more specifically for structural priming, Pickering and Branigan (1998).

3.1. AG circuits

Figure 1 shows how an AG can be visualised as a circuit of nodes. Memorised utterances are represented as circled words (nodes) connected with black horizontal arrows. Upward blue arrows point to AG categories. Category C1, for instance, corresponds to AG1_1, the first utterance position in AG1. Category nodes are also connected with black horizontal arrows. AG nodes and connections are assumed to constitute the *AG stratum* or *layer*. Nodes in the AG layer receive connections from nodes in the *Lexical layer* (brown arrows in Figure 1). These latter nodes may be thought of as representing base forms or stems of words ("lemmas") besides morphologically complete word forms and also morphemes embodying features of grammar like e.g. *–s* for 3rd person singular, symbolised as *–s(V)* in Figure 1. Additionally, we possibly allow word combinations i.e. utterance fragments or holophrases to be represented in the Lexical layer. Lexical nodes may be connected to other lexical nodes as the lines and arrows indicate. Finally, lexical nodes receive input from nodes of the *Concept/Semantic layer* representing conceptual units/objects.

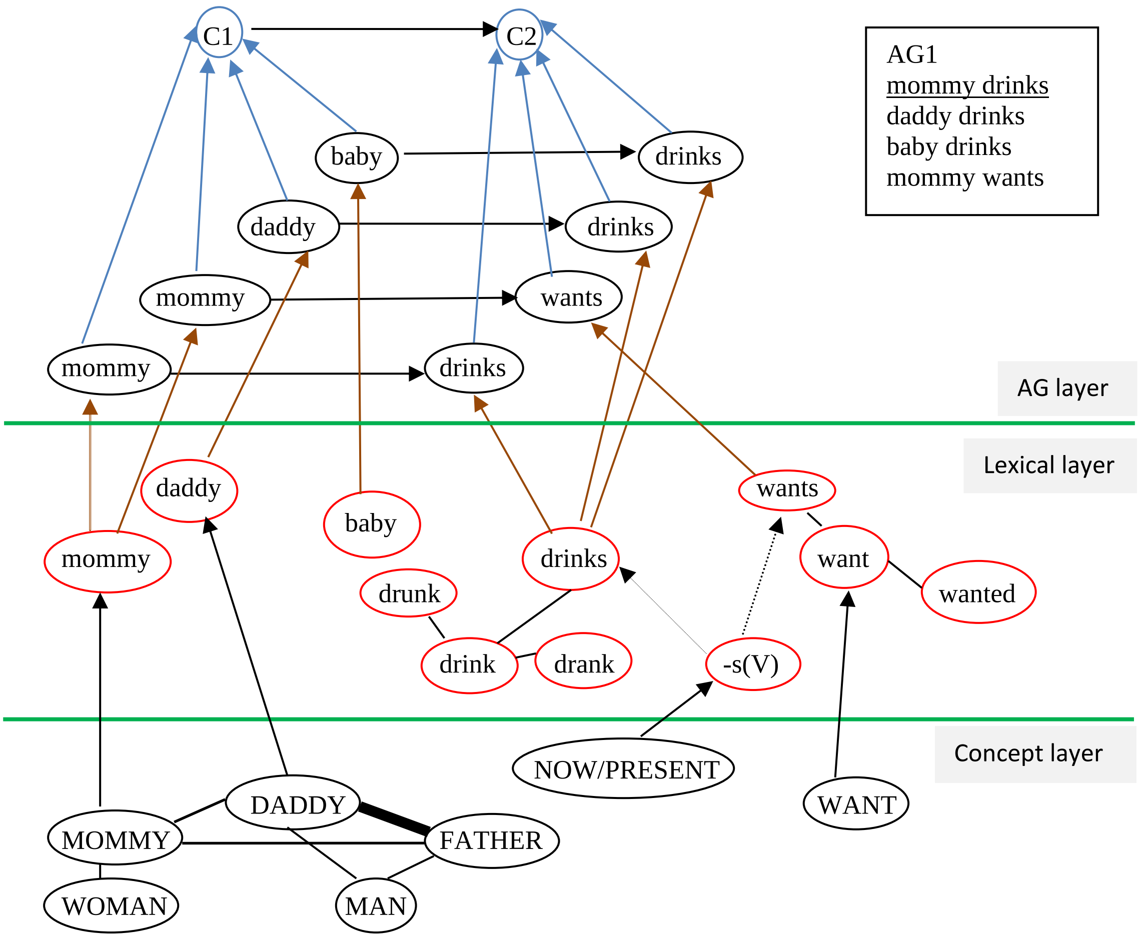

Figure 1. AG1 as circuit of nodes. See explanation in text.

Naturally, the picture we outline here should be regarded as approximate and it can be refined in many ways. First of all, we do not exclude the possibility of other types of connections across or within layers. For instance, there might be a single node representing a particular AG receiving input from the category nodes (C1 and C2 in Figure 1) and/or directly from the lower nodes of the AG. Memorised utterances could likewise be represented by corresponding unique nodes, even potentially in the Lexical and/or Concept layers. These utterance nodes could then be activated directly from other cognitive modules or layers for providing faster access (i.e. without the need to follow the pathways within AGs) for more automatic or "formulaic" language. Also, connections between nodes may somewhere be bidirectional or undirected, most dominantly, perhaps, in the "semantic network" of the concept layer. Furthermore, the strength of links between nodes may be graded. Clearly, there is a semantic connection between DADDY and MOMMY – both are parents – but the connection between DADDY and FATHER should somehow be stronger, as indicated with a thicker line, since both refer to the more specific concept MALE PARENT. Similarly, the dotted arrows in the Lexical layer refer to weaker connections. Undirected lines may alternatively be understood as bidirectional. As there is no sharp distinction between AGs and CSs (a single AG can cover a simple utterance), we shall explicitly use the notion *Coverage layer* only when a distinction between AGs and CSs is relevant. Also, we tacitly assume that further cognitive layers exist and can interact with those introduced here.

Through the example of *daddy wants,* Figure 2 demonstrates how an utterance can be processed by mapping it onto AG1 via activating the relevant nodes.

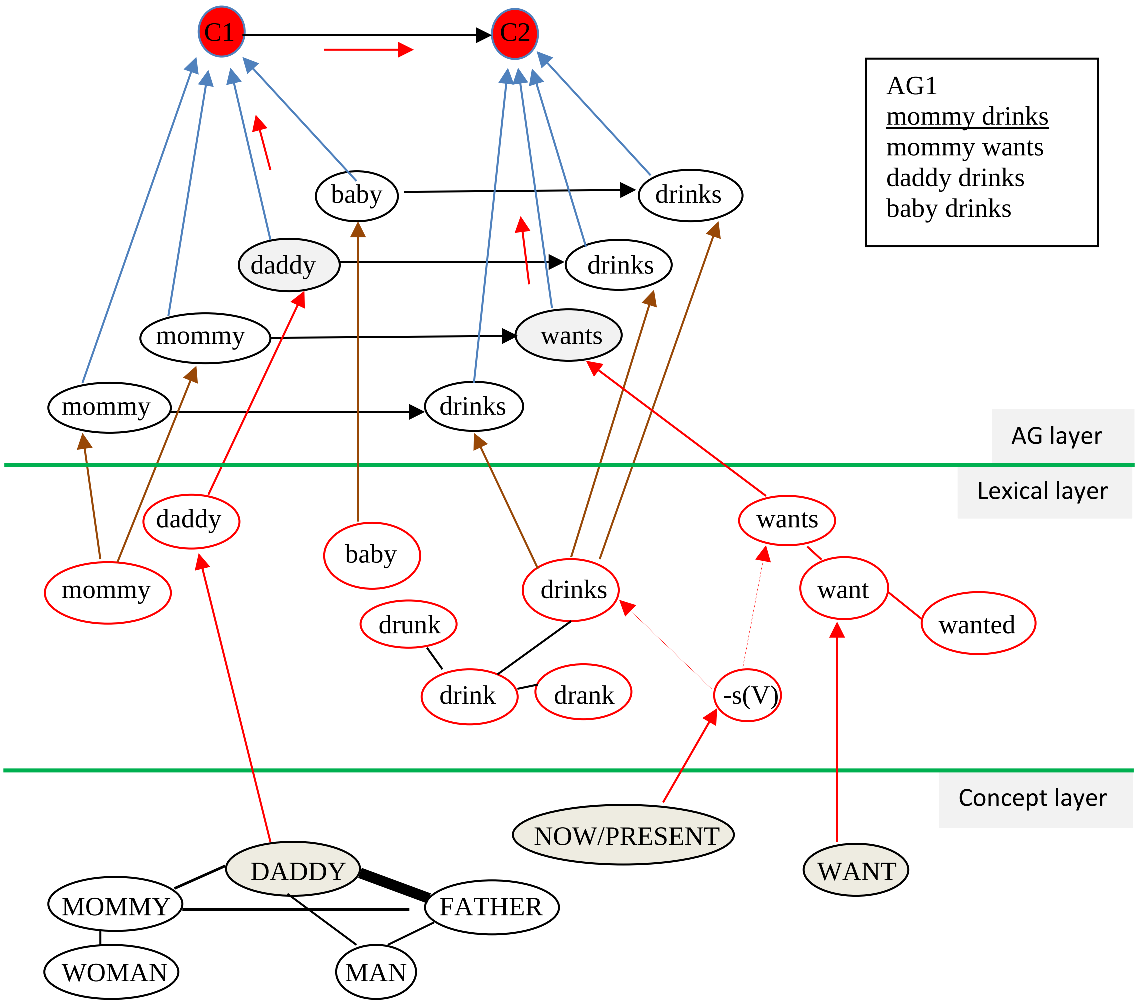

Figure 2. Mapping *'daddy wants'* onto AG1. Activation propagates as shown by red arrows

The "core" mapping process concerns the Lexical and the AG layers. The activation of nodes in the Lexical layer spreads along the corresponding connections and reaches the lower nodes of the AG, as the solid red arrows indicate. From the activated *'daddy'* node and *'wants'* node of AG1, activation spreads further to the category nodes (blue arrows) and the connection between them. As a general requirement for mapping to be complete, we can prescribe the possible activation of all category nodes in the AG (red filled circles). However, in the case of memorised group member utterances, e.g. *mommy drinks*, activation can spread along the horizontal black arrows for enabling faster processing which may or may not concern category nodes. Note the *'drinks'* nodes can also get activation from the morphological *-s(V)* node representing 3rd-person-singular but they do not become active. One possible explanation is that connections from morphological nodes are weaker, as indicated with the dotted arrows, and, alone, are not capable of activating the corresponding verb nodes of the Lexical (and thus ultimately the AG) layer. Another possibility would be that the verb stem and the *-s* suffix are represented as separate nodes (columns) in the AG so that both the verb stem and the suffix require their separate activating connections from the Lexical layer. The present figures incorporate the former explanation for easier visualisation. However, the latter, more refined picture could be invoked for discussing why lexical boost seems to be unaffected by word form variation (Pickering and Branigan, 1998). See also the remarks concerning the viability of morphological CSs, illustrated in (20) and Table 31 in Section 4.7

We assume this basic mapping process, associated primarily with the Lexical and the AG layers, to be shared by both production and comprehension mechanisms of language. Fundamentally, we ascribe the difference between the two processing modes to the additional cognitive domains involved. For instance, in comprehension, initial auditory stimuli may activate both lexical and conceptual nodes, either simultaneously or in a serial manner with lexical nodes activated first. In this latter case bidirectional links between lexical and conceptual nodes could support the "backward" propagation of activation from the Lexical to the Concept layer. The production process may or may not be triggered by external (visual, auditory, etc.) stimuli. In the absence of external stimulation, the AG mapping process might roughly be depicted as in Figure 2 but with connections to articulatory circuits responsible for the physical production of speech sounds.

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The combination of AGs into representations for CSs may also be pictured as realised by dedicated circuits. The nodes and connections that form such CS circuits might be collectively referred to as the Coverage layer. Figure 3 illustrates how AG1 and AG5 can be combined to yield CS_{AG1AG5}, as shown in (9), for *daddy wants tea.*

(9) CS_{AG1AG5}

daddy	*wants*	*tea*	
daddy	wants		AG1
	wants	tea	AG5

⟸

AG1
<u>mommy drinks</u>
daddy drinks
baby drinks
mommy wants

+

AG5
<u>drinks tea</u>
drinks milk
wants tea

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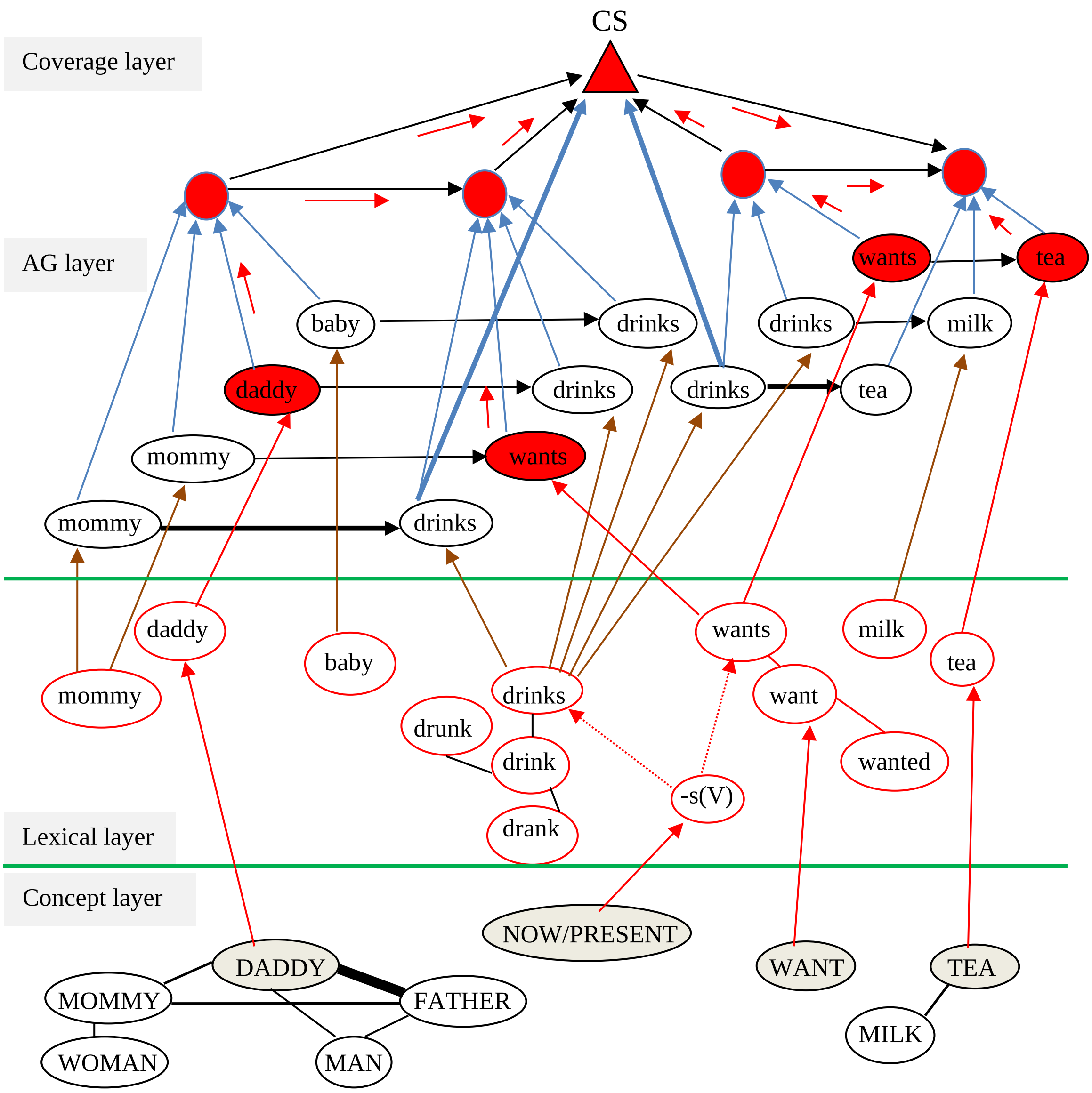

Figure 3. Coverage structure for '*daddy wants tea*'

Suppose utterances *mommy drinks* and *drinks tea*, as well as the utterances in their AGs, are stored in memory. A later utterance e.g. *mommy drinks tea* may inform the language learner that *mommy drinks* and *drinks tea* can be conjoined to form a novel utterance. This information can further be generalised to the AGs involved and can become hardwired into the cognitive circuitry. In our example, the conjunction of *mommy drinks* and *drinks tea,* and the respective AGs, is symbolised by the emergence of a new node, denoted by a triangle, receiving connections from the nodes representing the shared word '*drinks'* as well as from the category nodes in AG1 and AG5. This new mapping circuit can now be mobilised for processing novel utterances like *daddy wants tea* consisting of speech fragments that can be mapped onto the AGs in the circuit. Figure 3 shows that *daddy wants* can be mapped onto AG1, while *wants tea* onto AG5, and all category nodes plus the newly created structural node (triangle) become activated signalling the compatibility of *daddy wants tea* with CS_{AG1AG5}.

As every node can be connected to many others, it is not surprising that activation from lexical and conceptual nodes can fully activate alternative AGs for the same intended message. For instance, the concept DADDY WANTING TEA can be expressed by the active sentence *daddy wants tea* or by the passive *tea is wanted by daddy*. Figure 4 illustrates – given AG1, AG5, AG8, and AG13, as in (10) – how activation can spread across layers to reach a particular CS alternative. The solid red arrows indicate the choice for active, CS_{ACT}. The nodes and connections along the arrows can retain a certain degree of activation after the CS in question is accessed (especially the category and CS nodes in the circuits of the AG and Coverage layers) which can give rise to structural priming owing to easier access to the same CS for a subsequent utterance. Thus, *daddy wants tea* can prime e.g. *baby drinks milk*. Note that in Figure 4, the network representation is abandoned at the AG and Coverage layers for simplicity.

(10)

AG1	AG5	AG8	AG13
mommy drinks	drinks tea	tea is drunk	by daddy
daddy drinks	drinks milk	milk is drunk	by baby
baby drinks	wants tea	tea is wanted	
mommy wants			

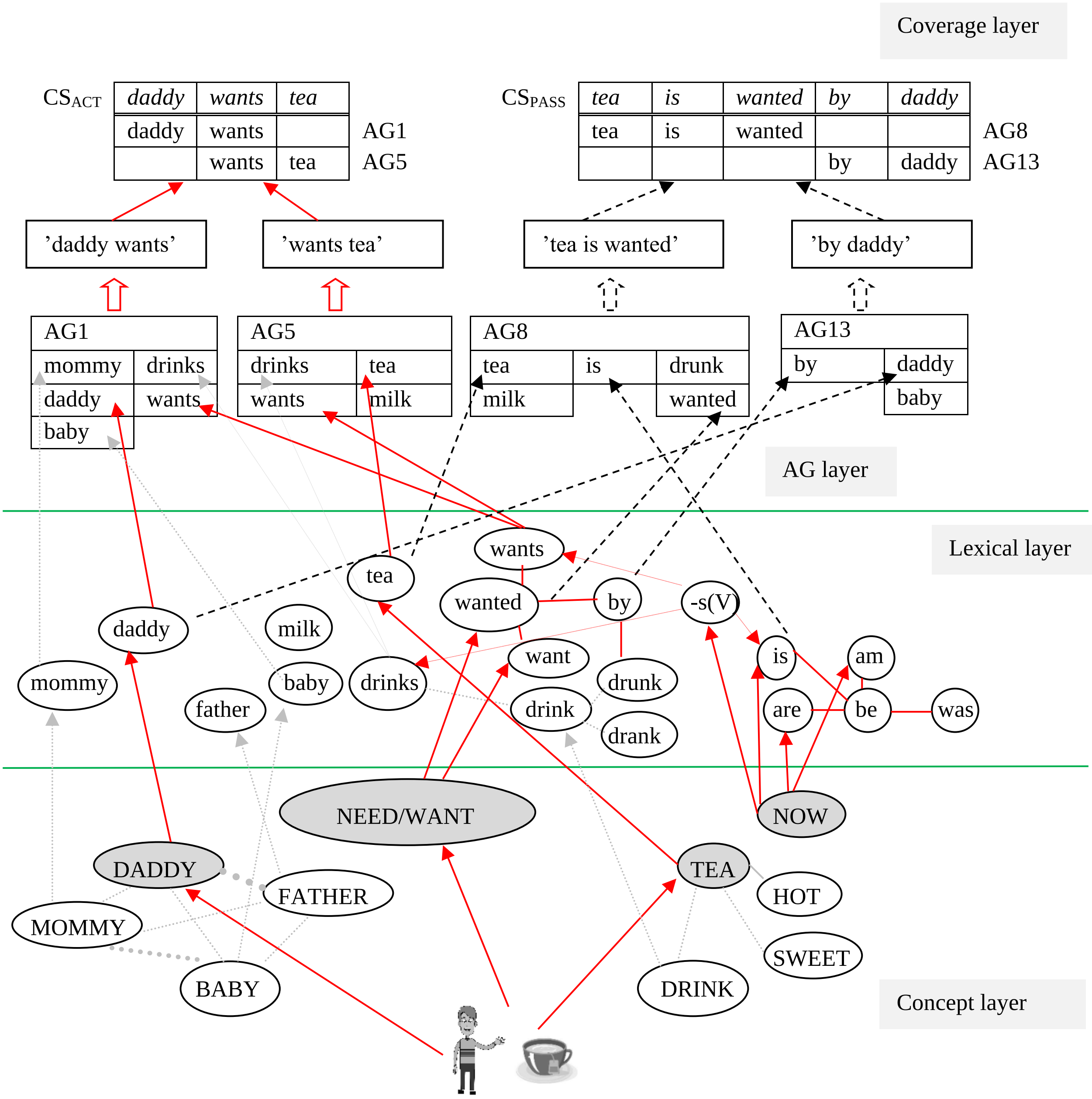

Figure 4. Alternative structures for expressing concept DADDY WANTING TEA: active and passive. When e.g. CSACT, the active construction, is chosen, following the solid red arrows, the corresponding nodes and connections retaining (some) activation can effect priming by constituting a subsequent bias for active. Dashed arrows lead to the alternative passive construction CSPASS. Dotted (red or grey) arrows or lines denote weaker activation.

3.2. *Semantic/lexical boost*

The AG circuitry model allows the connectivity structure of the Concept layer to have an influence on the activation level of the AG nodes and connections. In other words, conceptual or semantic relations have the potential to affect syntactic processing. In Figure 4, for instance, the '*drink'* node in the Lexical layer may receive activation from the conceptual DRINK node because it is contained in the same semantic circuit as concept TEA. However, since the TEA concept is activated "directly" whereas DRINK is activated indirectly, via semantic connections, the lexical '*drink'* node receives less activation which is insufficient to properly activate lexical '*drinks*' even though '*drinks'* is also (weakly) stimulated by the *'-s'* suffix node, cf. the grey dotted lines in Figure 4. Ultimately, the realisation of '*drink*' forms in the AGs is not supported by appropriate activation level, so *daddy wants tea* wins out over *daddy drinks tea*. However, if we assume, following Pickering and Branigan (1998), that previous activation can facilitate subsequent processing, and additionally assume that this is also true for "weakly" activated nodes and connections, we can expect a semantic facilitative effect for conceptually similar linguistic elements. Indeed, semantic boost to structural priming is a well-established notion in psycholinguistics. For instance, Cleland and Pickering (2003) observed that utterance *the sheep that is red* (as opposed to *the red sheep*) is primed more by *the goat that is red* than by *the knife that is red*. This means that there is a semantic relatedness/similarity factor influencing the magnitude of structural priming. In the AG model, semantic priming effects can be ascribed to an interplay between AGs and the semantic circuits of the Concept layer. On the one hand, semantically similar words may tend to belong to similar AGs and/or AG categories. On the other hand, in the semantic circuitry of the Concept layer, related words belong to the same circuit. Supposing, for instance, that AG55 exists, besides AG1 and AG5, we would expect that *mommy wants knife* primes *daddy wants fork* more than it primes *daddy wants tea*, cf. (11). This is because *mommy wants knife* and *daddy wants fork* are covered by the same AGs, AG1 and AG55, while *daddy wants tea* requires AG5 instead of AG55, i.e. it only shares AG1 with *mommy wants knife*. The respective CSs are shown as Tables 8, 9, and 10. Note that *'fork'* and '*knife'* belong to category AG55_2 whereas '*tea'* has category AG5_2. Conceptually, the nodes for AG55_2 words might be accessed from a NECESSARY THINGS or a CUTLERY circuit of the Concept layer whilst AG5_2 nodes should rather be connected to concept DRINK. Speculating a bit further, we might also expect that *mommy wants knife* primes *daddy wants fork* more than it primes *daddy wants money* since knife and fork must be more strongly connected to each other in the Concept layer than either of them to MONEY, even though '*money'* is also an AG55_2 word. Naturally, the argumentation here presupposes a capacity of conceptual connection strengths to have an influence on the activation level of AG nodes. Additionally, the capacity of semantic connections and connection strengths in the Concept layer to affect the activation of AG nodes could play a role in establishing sub-categories or concepts within AGs (see Section 1.1.5). For instance, pathways originating from conceptual circuit nodes (with about the same connection strength) could point to assemblies of AG nodes representing the realisation of the corresponding concept within a particular AG. Pathways from the appropriate nodes of a CUTLERY circuit (viz. KNIFE and FORK) to the '*knife'* and '*fork'* nodes of AG55 could define a KNIFE ∨ FORK realisation of the CUTLERY concept for AG55.

(11)

AG1	AG5	AG55
<u>mommy drinks</u>	<u>drinks tea</u>	<u>needs money</u>
daddy drinks	drinks milk	needs knife
baby drinks	wants tea	wants money
mommy wants		needs fork

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Table 8
CS for 'mommy wants knife'

mommy	*wants*	*knife*	
mommy	wants		AG1
	wants	knife	AG55

Table 9
CS for 'daddy wants fork'

daddy	*wants*	*fork*	
daddy	wants		AG1
	wants	fork	AG55

Table 10
CS for 'daddy wants tea'

daddy	*wants*	*tea*	
daddy	wants		AG1
	wants	tea	AG5

Note that a special case of semantic priming is when not a semantically related word is repeated in a subsequent utterance but the very same word. Alternatively speaking, the semantically most similar word is repeated, i.e. the original word itself. In such cases a stronger priming effect, the "lexical boost", is observed (e.g. Pickering and Branigan, 1998). The stronger priming effect in the case of lexical repetition is in line with our AG circuitry model since a previously activated lexical node might be easier to access for a subsequent utterance. While lexically independent structural priming may mostly be driven by the residual activation of category and CS nodes and connections in the AG/Coverage layer, the additional pre-activation of lexical (plus conceptual) nodes and connections can result in the pre-activation of a larger segment of a relevant pathway, which suggests a larger priming effect.

Pickering and Branigan (1998) provide a "one-locus" explanation of structural priming and lexical boost which is based on the lexical access model of Levelt et al. (1999) where lemmas (ca. base forms of words) constitute a cognitive stratum and are associated with grammatical features. Pickering and Branigan (1998) further propose that lemmas be linked to combinatorial nodes responsible for particular constructions. Priming, then, is due to residual activation of combinatorial and lemma nodes, as well as the corresponding connections. In particular, lexically independent structural priming occurs as a result of the residual activation of the combinatorial nodes, whereas lexical boost is the consequence of the additional residual activation of lemma nodes and their links to combinatorial nodes. Furthermore, since the same lemma is activated for different morphological forms of the same verb, it is not necessary for prime and target to share the same form of the given verb for a lexical boost effect to come about, in accordance with the authors' (P. and B.) observations.

The AG circuitry approach offers a more fine-grained picture of the residual activation model. The category and/or CS nodes belonging to the AG and the Coverage layers – responsible for lexically more independent syntactic processing and priming – could collectively be termed "combinatorial nodes", whereas lexical nodes represent "lemmas", whose residual activation, possibly reinforced by concept nodes, boosts structural priming lexically. The AG model suggests that semantic priming is additionally a manifestation of interaction with conceptual circuits.

3.3. Cross-linguistic priming

Bernolet, Hartsuiker, and Pickering (2007) extend Pickering and Branigan's model in order to account for bi- or multilingual findings. In this integrated network, lemma nodes of a shared lexicon are tagged according to which language they belong to and lemmas representing the same meaning in different languages are connected to a shared node at the conceptual level, as well as to a shared syntactic category node (e.g. 'noun'). Each lemma node is linked to the combinatorial nodes representing the linguistic constructions in which the given lemma/word can participate in the language the lemma is tagged to. The AG model can, likewise, accommodate multilingual phenomena. Figure 5 and the AGs in (12) shows how the concept DADDY WANTING TEA can be realised either in English as *daddy wants tea* or in Hungarian as *apa akar teát.* Note that in Hungarian, other word order variants, e.g. *apa teát akar* are also possible.[4] The English lemmas are connected to their Hungarian equivalents (blue lines) and lemmas of both languages are also linked to the corresponding (shared) concept nodes in the Concept layer (black and green arrows). An arrow connecting a grey box to a language concept (ENGLISH or HUNGARIAN) means that all the lemmas within the box are connected to that language concept. Activation can propagate in parallel from conceptual nodes to alternative AGs and CSs in both languages. Suppose, for example, that CS1 gets activated for processing utterance *daddy wants tea.* Then, consequently, pathways for alternative English constructions (e.g. for passive) become deactivated or suppressed. After processing the utterance, the CS1 pathways retain some activation, a certain amount of which can be shared with the corresponding Hungarian nodes via the lexical connections (blue lines) and/or the conceptual connections (green arrows) to result in priming for Hungarian AGs and CSs. Note that in our example, *daddy wants tea* would prime both Hungarian word-order variants, CS2 (e.g. *baba iszik tejet 'baby drinks milk')* and CS3 (e.g. *baba tejet iszik 'baby milk drinks'*).

(12)

AG1	AG5	$AG_{HU}1$	$AG_{HU}5_{VN}$	$AG_{HU}5_{NV}$
mommy drinks	drinks tea	anya iszik	iszik teát	teát iszik
daddy drinks	drinks milk	apa iszik	iszik tejet	tejet iszik
baby drinks	wants tea	baba iszik	akar teát	teát akar
mommy wants		anya akar		

[4] There are topic-focus issues concerning word order, whose details are irrelevant with respect to our arguments here, so they are not included in our discussion.

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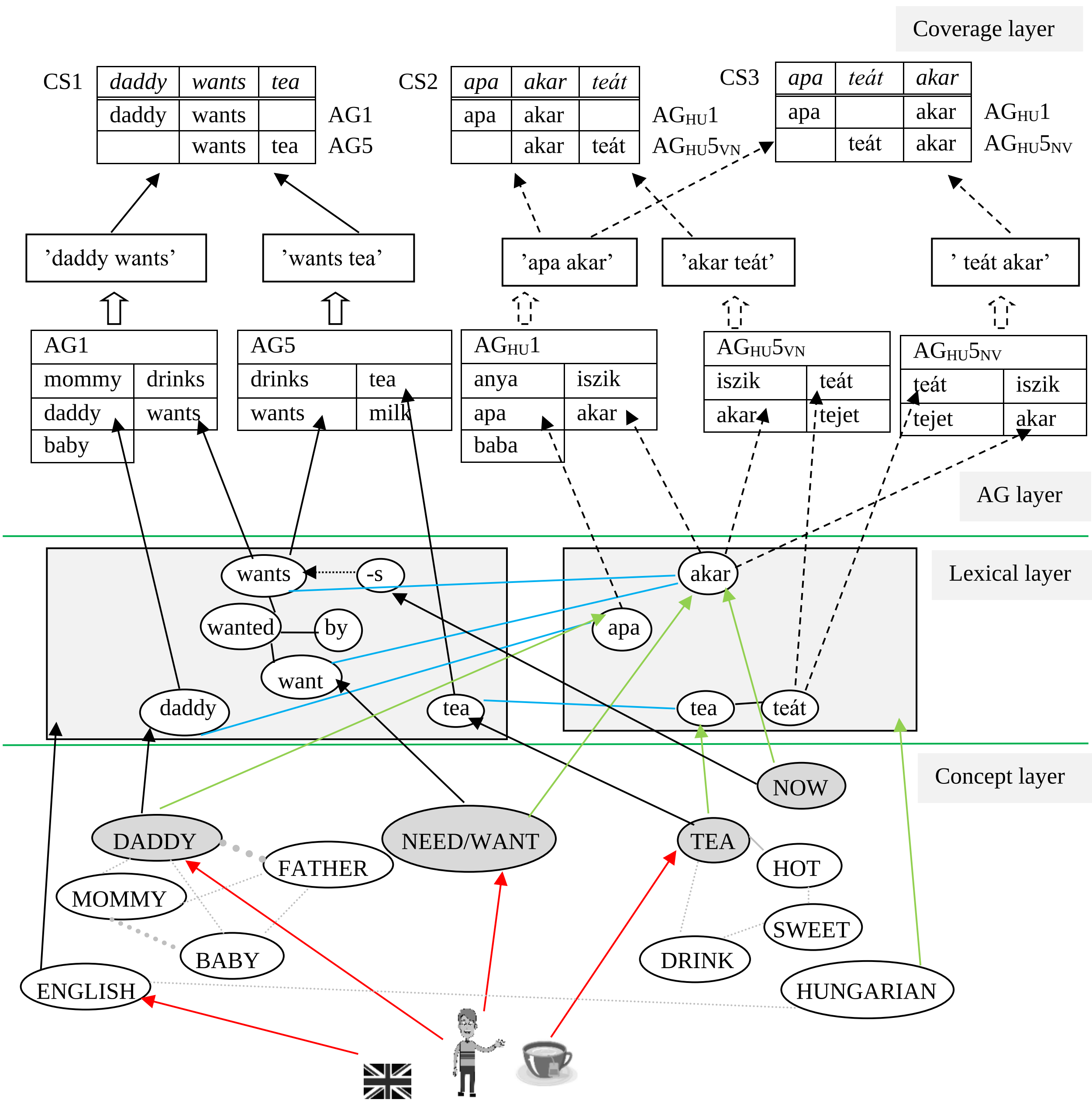

Figure 5. Cross-linguistic mapping alternatives. Concept DADDY WANTING TEA can ultimately activate CS1 for the English utterance *daddy wants tea* as well as CS2 and CS3 for the Hungarian equivalents. Black arrows from concepts point to English lemmas, and green arrows to Hungarian ones. Blue lines indicate direct links between English and Hungarian nodes. An arrow from a language concept (ENGLISH or HUNGARIAN) to a grey box means that all the lemmas within the box are connected to that language concept. Concepts are labelled with capitalised English words.

Research findings from behavioural experiments do not seem to be unequivocal with regards to cross-linguistic structural choice. Loebell and Bock (2003), for instance, reported cross-linguistic priming between German (L1) and English (L2) in a picture description task for datives. Bernolet et al. (2007) found no priming of complex noun phrases between Dutch (L1) and

English (L2) where word order for the noun phrases in question is different in the two languages (e.g. "*The sheep that red is"* vs. *The sheep that is red*). On the other hand, Bernolet, Hartsuiker, and Pickering (2009) did observe priming, in spite of the word order difference, between verb-final passives in Dutch and verb-medial passives in English (e.g. "*The diver was by the pirate lifted*" vs. *The diver was lifted by the pirate).* The AG model would suggest that complex noun phrases are less similar cross-linguistically (cf. the lack of priming effect) as they reflect AG-level differences: speech fragments *red is* and *is red* are not likely to be in cross-linguistically equivalent AGs. On the other hand, the Dutch and the corresponding English passives share cross-linguistically equivalent fragments, with the difference that the Dutch '*by the pirate'* phrase is embedded in the discontinuous *was lifted* fragment whereas in English the fragments do not require discontinuity. Consequently, we might conclude that the AG-level word order difference for complex noun phrases distorts structural similarity more than does the CS-level word order difference for passive.

Alternative explanations[5] may include reference to memory processes. Arguably, a previously processed utterance can be represented in short-term memory (STM) as an ordered sequence of words. In that case, lexical nodes could be linked to, and receive activation from, memory nodes corresponding to the items in STM. Besides residual activation of the previously operative pathways, then, memory nodes could also contribute to priming. As we assume that word-order would be sustained in STM, the cross-linguistic data could be explained by a conflict between sequential word order and AG-mapping order. Since *The sheep that is red* sequence in STM would require an AG where *'is'* is represented before the adjective (activation propagating towards '*red'*) its memory trace could not sufficiently support mapping onto a Dutch AG prescribing mapping *'is'* after an adjective. On the other hand, the memory trace of *The diver was lifted by the pirate* could provide more priming for the Dutch verb-final passive since word order within either of the corresponding Dutch AGs (for '*was lifted*' and '*by the pirate*') could be in line with the word order imposed by the memory trace of the English sentence, i.e. every word within a Dutch AG would be followed by a word that comes later in the memory trace.

As for the Hungarian examples, in the absence of extra-syntactic factors, the AG model might consider CS2 (for *apa akar teát*) as a more probable target to be primed by the English sentence than CS3 (for *apa teát akar*) because CS2 requires the same activation sequence of words as CS1. Consequently, *daddy wants tea* would prime e.g. *apa akar teát*. Alternatively, we could say that CS2 is more similar to CS1 than CS3 is because CS3 involves a discontinuous fragment, $AG_{HU}1$, and there is an AG-level word-order difference between AG5 and $AG_{HU}5_{NV}$.

Kootstra, van Hell, and Dijkstra (2010) demonstrate that code-switching between languages in Dutch-English bilinguals can occur during sentence processing and it can influence word order choice with a preference for constructions where the word order is identical in the two languages. The

[5] Note that alternative explanations are provided in order to be confirmed or falsified by future research. They are not necessarily mutually exclusive, as they may have overlapping details. In the present example, for instance, AG reactivation may depend on memory processes.

findings are in concert with the AG circuit framework enabling code-switching at any utterance position. Suppose that, in our example, an English-Hungarian bilingual speaker starts processing *daddy wants tea* but after activating the lexical '*daddy'* node and reaching the corresponding AG1 node this speaker is cued to switch to Hungarian. Since the corresponding Hungarian lexical nodes also receive some activation, either directly from the English lemmas or through conceptual links, the Hungarian groups $AG_{HU}1$, $AG_{HU}5_{VN}$ and $AG_{HU}5_{NV}$, also become available licensing both CS2 (*apa akar teát*) and CS3 (*apa teát akar*). Thus, in principle, both hybrid sentences, *daddy akar teát* and *daddy teát akar* could be produced. However, AG1 has already been activated by the '*daddy*' pathway and anticipates a verb (*drinks* or *wants*). This requirement can be fulfilled by activation from the lexical '*wants*' if we assume, logically, that all the relevant concepts become active before lexical and AG mappings begin and therefore the lexical '*wants'* node has also been activated by a corresponding concept. As AG1 is now fully active, it can have an influence on the choice of the corresponding Hungarian CS. $AG_{HU}1$ also prescribes a noun-verb temporal sequence but in CS2 it is employed continuously while in CS3 it needs discontinuous mapping. Consequently, CS2 is more similar to the English CS1, and we would expect the mapping process to be guided in the direction of *daddy akar teát*.[6] The similarity of CSs, again, plays a role in explaining experimental findings, namely, findings on code-switching and a bias for constructions with shared word-order.

3.4. Short-lived versus long-lived structural priming

Branigan, Pickering, and Cleland (1999) revealed that priming effects are short-lived when prime and target share a verb, i.e. the effect was diminished when prime and target was separated by a neutral sentence and completely disappeared with four intervening sentences (see also Levelt and Kelter, 1982, where one intervening sentence cancelled the effect). However, experiments where verbs are not repeated find long-lived priming, undiminished and detectable after 10 intervening neutral sentences (e.g. Bock and Griffin 2000), or even for weeks (Kaschak, Kutta, and Coyle, 2014). The AG circuitry model offers the following explanation. AGs are represented as node configurations and, additionally, a particular construction can be represented by multiple AGs. This means that the processing of a given utterance can involve fairly large node populations of the AG layer. Activation in such circuits may be much more likely to be maintained for longer time periods than the activation of individual nodes or smaller circuits in the Lexical layer, where we do not expect large populations of interconnected nodes.[7] Thus, AG circuits can intrinsically support long-lasting structural priming. In contrast, lexical facilitation, as effected by the repetition of individual words, may span a shorter time interval due to intrinsically shorter activation maintenance in less densely interconnected lexical pathways. However, this explanation, alone, would mean that when short-lived lexical facilitation disappears, after some

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[6] Recall that we ignore topic-focus issues.
[7] Our intuition about longer-lived memories for larger neuronal populations with larger connectivity may be confirmed by empirical data. Benna and Fusi (2016), for instance, report a linear relationship between memory lifetime and number of neurons (synapses) in a computational experiment with a class of synaptic models.

intervening sentences, structural priming should be the same as without lexical facilitation, it should not disappear. A more precise characterisation of the phenomenon may relate to memory processes besides just differences in connectivity. A key observation in memory research is that repeated stimuli in primates can result in two types of neuronal activation: neuronal responses can be *suppressed* or they can be *enhanced* (e.g. Miller and Desimone, 1994). In our context, suppression may mean that when content-words are repeated – i.e. their lexical nodes are re-accessed through connections from conceptual nodes (production) or by oral/written stimuli (comprehension) – the activation level of the corresponding lexical nodes will be diminished compared with the first activation.[8] The low activation of suppressed lexical nodes (and connections) then might not be enough to facilitate, or might inhibit, re-access to the relevant AGs. Therefore, we expect a reduced (short-lived) structural priming effect for repeated words, in general. On the other hand, enhanced responses may reflect a more active involvement of STM (Miller and Desimone, 1994) for repetitions closer in time. Repeated words in consecutive utterances may be temporally close enough to trigger an active memory search for repetitions (versus a more automatic repetition detection mechanism associated with response suppression). Repeated elements detected by this more active search mechanism, in turn, may raise the activation level of the corresponding lexical nodes thereby possibly adding to their residual activation facilitating easier access to previously operative AGs, i.e. contribute to lexical boost. Thus, the AG circuitry model is compatible with an interpretation of priming phenomena where structural priming is long-lived because large AG populations might maintain more long-lasting activation, whilst lexical priming is primarily short-lived as a result of suppressed activation of lexical nodes for distant repetitions, with a boost for only temporally close word repetitions resulting from enhanced lexical activation effected by more intensive STM involvement.

Note that our assumption about possibly more prolonged activation in AG circuits is in line with a view that structural priming relates to adaptation mechanisms underlying implicit learning (e.g. Bock and Griffin, 2000; Chang et al., 2006). Sustained activation may entail Hebbian strengthening and weakening of connections between AG nodes and therefore can have a long-lasting effect on the structure of the AG and Coverage layers. For one thing, AGs representing certain construction types can gain priority over others responsible for alternative constructions due to possibly easier accessibility through stronger links. Furthermore, by assuming that "neglected" or suboptimal connections get weaker we obtain a mechanism for explaining how AG circuits can be homogenised (see Section 1.1.3). Connections along pathways representing suboptimal utterances in AGs can become weak enough to be prohibitive, i.e. unwanted utterances can get excluded from AGs. Thus, since we relate homogenisation to error correction, AG circuits can be seen as also having an error-driven developmental feature.

[8] Note that we only expect priming effects for content-words, i.e. not for function-words (cf. e. g. Pickering and Branigan, 1998). However, the same argumentation may hold for function-words, too, with the difference that priming effects stay unobservable since suppressed or enhanced activation might dissipate along the weaker and/or more diverse connections that we suppose for lexical nodes representing grammar-related information.

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4. AG account of structural priming phenomena

In this section we illustrate via a "classic" blend of examples how the fundamental notions of the AG model can be employed in explaining findings from experiments investigating particular structural priming phenomena. In our discussion we shall deploy hypothetical AGs for a subset of English containing the phenomena to be examined. We shall attempt to use the simplest or most instructive analyses. Example sentences will be short, determiners, adjectives, or phrasal sentence constituents of no direct importance with regards to the particular construction will be omitted. AGs will be represented by just a small number of member utterances. Our analyses, especially the composition of CSs, should not be understood as exclusive. Appropriate alternative AG combinations could generally yield similar results. Recall that speech fragments represented by AGs do not necessarily coincide with phrase-structure constituents, which is a consequence of our usage-based attitude.

4.1. Double Object Dative versus Prepositional Object Dative

Besides active versus passive sentences, Bock (1986) also reported structural priming for the dative constructions Double-object Dative (DOD), and Prepositional Object Dative (POD). Furthermore, POD sentences with prepositions '*to*' or '*for*' equally primed the production of '*to'* in target POD sentences. Suppose a hypothetical speaker's AG collection includes groups AG15, AG16 and AG17 as shown in (13). Table 11 demonstrates how two groups, here AG15 and AG16, can be combined into CS_{POD} licensing a POD sentence, e.g. *baby brings tea to mommy*. In contrast, CS_{DOD} given as Table 12 symbolises the discontinuous combination of AG15 with AG17 for DOD utterances, say *baby brings mommy tea*. In the examples, priming means that a previously activated CS constitutes a bias for subsequent processing. After mapping *baby brings mommy tea* onto CS_{DOD}, for instance, the DOD sentence *mommy gives daddy juice* will be more probable than the POD alternative *mommy gives juice to daddy*. Similarly, CS_{POD} will prime POD utterances. Note that AG16 allows several prepositions which entails that both *baby brings tea* ***to*** *mommy* and *baby brings tea* ***for*** *mommy* are mappable onto CS_{POD}, i.e. both sentences could prime *mommy gives juice to daddy*, in accordance with the experimental findings. As other prepositions might also be possible in AGs, they could also contribute to the POD priming effect. *Baby brings tea* ***with*** *mommy*, for instance, could prime POD utterances, supposing that AG16 is not homogenised further. This might be a research question to investigate in more detail.

(13)

AG15	AG16	AG17	AG18
<u>baby brings tea</u>	<u>to mommy</u>	<u>gives mommy tea</u>	<u>John said that</u>
baby gives tea	to daddy	brings mommy tea	Jack said that
baby brings bread	for mommy	gives mommy juice	John says that
mommy brings tea	with mommy	gives daddy tea	
baby brings juice	to baby		

Table 11

Coverage structure CS_{POD} for processing 'baby brings tea to mommy'

baby	*brings*	*tea*	*to*	*mommy*	
baby	brings	tea			AG15
			to	mommy	AG16

Table 12

Coverage structure CS_{DOD} for processing 'baby brings mommy tea'

baby	*brings*	*mommy*	*tea*	
baby	brings		tea	AG15(discontinuous)
	brings	mommy	tea	AG17

Our claim that discontinuous mapping spoils CS similarity is also confirmed by experiments with shifted-object constructions. Pickering, Branigan, and McLean (2002), e.g., found no priming of shifted-object target sentences from the POD construction. As Table 13 illustrates, the object shifting CS_{ShO} may employ the same AGs as CS_{POD}, viz. AG15 and AG16, but it requires discontinuous mapping onto AG15. Consequently, we do not expect the POD *baby brings tea to mommy* to significantly prime the shifted-object *mommy gives to daddy juice*.

Table 13

Coverage structure CS_{ShO} for processing 'baby brings to mommy tea'

baby	*brings*	*to*	*mommy*	*tea*	
baby	brings			tea	AG15(discontinuous)
		to	mommy		AG16

4.2. Subordinated clause versus main clause

Branigan, Pickering, McLean, and Stewart (2006) suggest that priming is a consequence of reusing particular "phrase-structure rules", regardless of the global structure of the sentences in question. They observed priming irrespective of whether the prime and/or the target involved a subordinate clause or not. For instance, *the girl gave the puppy to the boy* and *John said that the girl gave the puppy to the boy* behaved similarly with regard to priming. The priming effect was greater when prime and target shared the same sentence type, though. The results are in concert with our intuitive claim that the larger portions of the CSs for prime and target overlap, the larger priming effect may be observed. For instance, both *'baby brings mommy tea'* and *'John said that baby brings mommy tea'* can prime *'mommy gives daddy juice'*. However, whereas *'baby brings mommy tea'* and *'mommy gives daddy juice'* share the same CS_{DOD}, CS_{THAT} for *'John said that baby brings mommy tea'* contains the extra group AG18 from (13) which reduces the similarity of the CSs in question. A lesser degree of structural similarity for prime and target utterance, in turn, may result in a smaller priming effect, cf. Table 14 and Table 12.

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Table 14
Coverage structure CS_{THAT} for processing 'John said that baby brings mommy tea'

John	*said*	*that*	*baby*	*brings*	*mommy*	*tea*	
			baby	brings		tea	AG15(discontinuous)
				brings	mommy	tea	AG17
John	said	that					AG18

4.3. Locative versus agentive by-phrase

Bock and Loebell (1990) observe that sentences containing a locative by-phrase, e.g. *The foreigner was loitering by the broken traffic light* can prime passive sentences with agentive by-phrase, e.g. *The referee was punched by one of the fans*. We propose that, due to the ambiguity of preposition *'by'*, AGs containing it cannot dissociate fully with respect to locative or agentive function, cf. e.g. *he stood by the wall*, and *he was stopped by the wall*. Thus, AG19 in (14) need to be used for both $CS_{locative}$ and $CS_{agentive}$, given as Table 15 and Table 16, respectively. Cf. also AG20 and AG21 in (14).

(14)

AG19	AG20	AG21
by the wall	he stood	he was stopped
by the light	he waited	he was seen
by a wall	we stood	I was stopped
by the fan	you stood	

Table 15
Coverage structure $CS_{locative}$ for processing 'he stood by the wall'

he	*stood*	*by*	*the*	*wall*	
		by	**the**	**wall**	**AG19**
he	stood				AG20

Table 16
Coverage structure $CS_{agentive}$ for processing 'he was stopped by the wall'

he	*was*	*stopped*	*by*	*the*	*wall*	
			by	**the**	**wall**	**AG19**
he	was	stopped				AG21

The fact that *he stood by the wall* could prime e.g. *I was seen by a fan* suggests that priming effects might not require a full structural alignment of subsequent utterances (of prime and target). The presence of AG19 in $CS_{locative}$ for an active sentence, *he stood by the wall,* may suffice to bias the selection of the passive structure $CS_{agentive}$ also containing AG19, like for *I was seen by a fan*, instead of the active *a fan saw me*. In terms of similarity, we could say that the passive utterance *I was seen by a fan* is "coverage-structurally" more similar to the active *he stood by the wall* than is the active sentence *a fan saw me*.

4.4. Relative clause attachment

Scheepers (2003) reports a priming effect concerning relative clause attachment. Sentences like *The assistant announced the score of the candidate that...* are structurally ambiguous since they allow for two interpretations. In e.g. *The assistant announced the score of the candidate that was very good* the relative clause *that was very good* can be interpreted as either modifying noun-phrase *the candidate* ("low attachment") or *the score of the candidate* ("high attachment"). Assuming groups AG22, AG23, and AG24 in (15), there can be two distinct CSs for the two cases. In CS_{low}, the *candidate that was good* fragment of the sentence is mapped onto AG23 (low attachment), whereas in CS_{high} the *score that was good* fragment is mapped onto AG23 discontinuously (high attachment). Depending on which CS is activated by the prime, CS_{low} or CS_{high}, the corresponding interpretation will be more easily available for a subsequent utterance, say *The author of the book that was bad*, cf. Tables 17 and 18.

(15)

AG22	AG23	AG24
<u>the score</u>	<u>score that was good</u>	<u>of the</u>
the candidate	score that is good	for the
a score	score that was bad	of a
the author	candidate that was good	
the book	book that was good	
	author that was good	

Table 17
Coverage structure CS_{low} for processing 'the score of the candidate that was good'

the	*score*	*of*	*the*	*candidate*	*that*	*was*	*good*	
the	score							AG22
			the	candidate				AG22
				candidate	**that**	**was**	**good**	**AG23**
		of	the					AG24

Table 18
Coverage structure CS_{high} for processing 'the score of the candidate that was good'

the	*score*	*of*	*the*	*candidate*	*that*	*was*	*good*	
the	score							AG22
			the	candidate				AG22
	score				**that**	**was**	**good**	**AG23(discontinuous)**
		of	the					AG24

4.5. Object-raising versus object-control

Griffin and Weinstein-Tull (2003) claim that speakers are more likely to produce a noun phrase and infinitive clause (e.g. *John believed Mary to be nice*) after prime utterances with object-raising (OR) verbs (e.g. *A teaching assistant reported the exam to be too difficult*) than after sentences with object-control (OC) verbs (e.g. *Allen encouraged his roommate to be more studious)*. In the sentence-recall experiments, speakers were expected to paraphrase finite complement clauses as infinitive clauses after producing an OR or OC sentence. The authors report i) a general infinitive priming effect resulting from the presence of an infinitive complement in the priming sentence, and ii) a specific infinitive priming effect due to the differential processing of OR and OC clauses. Additionally, iii) passive versions of the object-raising primes elicited fewer paraphrases than the active versions did. The first words of the given target sentence, including the OR verb, were used as the recall cue (e.g. *John believed…*). We sketch the relevant fragmentations in the CSs for a possible target (i.e. to be recalled) finite complement utterance and its possible primes as Tables 19 - 22. A first glance reveals that all primes contain shared infinitival fragments, *to be nice* or *Mary to be nice*, which can account for the observed general infinitive priming effect. As for the specific infinitive effect, it seems to reflect a more intricate interplay of priming from the target (sentence to be recalled) and priming from the prime (actually following the target), besides just CS similarity: the more similar the CS of the target to the CS of the prime, the more probable that the target becomes paraphrased into an infinitival sentence, i.e. the dominant priming effect comes from the prime. Conversely, if the prime is not similar "enough", the priming effect of the prime will be suppressed by the priming effect from the target. This might imply that repetition suppression/enhancement, as discussed in Section 3.4 concerning long-lived versus short-lived priming, may also pertain to repeated structural components, e.g. AGs, not only to words. Similarity, understood as correlating with structural repetitions across CSs, can affect priming in such a way that temporally distant repeated AGs may inhibit the re-activation of the CSs that previously deployed them and the word sequence of the to-be-recalled sentence is reassigned a new CS whose structural components may be facilitated by repetition enhancement and residual activation from the more recent prime. On the other hand, when the intervening sentence (prime) is not similar (enough) to the target, structural repetition effects do not interfere (so much) with sentence recall, so the original structure of the target can be maintained more efficiently.

To visualise the degree of similarity between the target and the various primes consider Tables 19 - 22. The initial part of the target CS_{targFC}, Table 19, and of the CS for the OR sentence CS_{OR} in Table 20, are fairly similar in that they both symbolise a group with OR verbs, say AG_{OR}. This similarity is somewhat reduced for the OC sentence, since (*John persuaded) (Mary to be nice)* is a less sensible segmentation than *(John persuaded Mary)(to be nice)*, cf. Table 21. Thus CS_{targFC} seems to have more in common with CS_{OR} than with CS_{OC}, hence CS_{OR} may be responsible for a larger priming effect. Note that the recall cue (e.g. *John believed*) can also be mapped onto AG_{OR}, equally biasing CS_{targFC} and CS_{OR} so its contribution to priming might be negligible. In terms of structural similarity, the passive version of the OR sentence, viz. *Mary* *was believed to be nice by John*, might be more reminiscent of an OC sentence than of the active OR sentence itself since the initial AGs of CS_{targFC} for mapping *Anne reported (that)* cannot be used for mapping *Mary was believed*, cf. CS_{ORpass} in Table 22. Consequently, as the passive OR structure is less similar to the target CS than the active OR structure is, the priming effect from the target is more dominant, i.e. fewer paraphrases can be expected from passive primes.

Table 19
Coverage structure $CS_{targ\ FC}$ for processing target 'Anne reported that Jill was good'

Anne	*reported*	*that*	*Jill*	*was*	*good*	
Anne	**reported**					**AG_{OR}**
		that	Jill	was	good	
Anne	reported	that				
			Jill	was	good	

Table 20
Coverage structure CS_{OR} for processing prime 'John believed Mary to be nice'

John	*believed*	*Mary*	*to*	*be*	*nice*	
John	**believed**					**AG_{OR}**
		Mary	to	be	nice	
John	believed	Mary				?
			to	be	nice	

Table 21
Coverage structure CS_{OC} for processing prime 'John persuaded Mary to be nice'

John	*persuaded*	*Mary*	*to*	*be*	*nice*	
John	persuaded					AG_{OR}?
		Mary	to	be	nice	?
John	**persuaded**	**Mary**				AG_{OC}
			to	be	nice	

Table 22
Coverage structure CS_{ORpass} for processing prime 'Mary was believed to be nice by John'

Mary	*was*	*believed*	*to*	*be*	*nice*	*by*	*John*	
Mary	was	believed						AG_{ORpass}
Mary			to	be	nice			
			to	be	nice			
						by	John	

4.6. Coerced expressions

Experimenting with coerced sentences Raffray, Pickering, Zhenguang, and Branigan (2014) observed that participants were less likely to produce coerced expressions (e.g. *the bricklayer began the wall*) after VP primes (e.g. *the author began writing the book*) than following either coerced (e.g. *the* *author began the book*) or event-NP primes (e.g. *the author began the lecture*). Assuming the AGs in (16), the corresponding CSs, are sketched as CS_{CO1} of Table 23 and CS_{CO2} of Table 24. While CS_{CO2} can be used for processing coerced sentences, CS_{CO1} is more complex as it has more groups (cf. AG_{CO3}), and involves AG_{CO2} discontinuously. Since the two CSs are quite different, we cannot expect CS_{CO1} to prime coerced targets as much as CS_{CO2} can prime them.

(16)

AG_{CO1}	AG_{CO2}	AG_{CO3}
the author	began the book	began writing
the book	began the article	began building
the article	began the wall	started writing
the wall	began the lecture	
the bricklayer	wrote the book	
the lecture	bought the book	
the speech		

Table 23
Coverage structure CS_{CO1} for processing 'the author began writing the book/lecture'

the	*author*	*began*	*writing*	*the*	*book/lecture*	
the	author					AG_{CO1}
		began	writing			AG_{CO3}
		began		**the**	**book/lecture**	$\mathbf{AG_{CO2}}$
				the	book/lecture	AG_{CO1}

Table 24
Coverage structure CS_{CO2} for processing 'the author began the book/lecture'

the	*author*	*began*	*the*	*book/lecture*	
the	author				AG_{CO1}
		began	**the**	**book/lecture**	$\mathbf{AG_{CO2}}$
			the	book/lecture	AG_{CO1}

Raffray et al. (2014) additionally observed that participants were more likely to produce coerced responses (*the bricklayer began the wall*) after coerced primes (*the author began the book*) than after event-NP primes (*the author began the lecture*). Syntactically, the constituent structures of the sentences in question are exactly the same. However, the respective CSs will be different if we, for instance, allow sub-AGs on the basis of concepts definable over AGs, and suppose that these AG sub-domains can have specific properties with respect to combinability. By assuming the concepts in (17) over AG_{CO1} along with the corresponding sub-AGs – AG_{CO1}/ANIMATE, AG_{CO1}/OBJECT, and AG_{CO1}/EVENT – we can have two different CSs. One for coerced utterances, e.g. CS_{OBJ} in Table 25, and another one for sentences with event-NP objects, e.g. CS_{EVENT} in Table 26. Obviously, CS_{OBJ} is a more suitable CS for *the bricklayer began the wall* to be mapped onto than CS_{EVENT} and can result in a larger priming effect.

(17)

"Animate": THE ∧ (AUTHOR ∨ BRICKLAYER)
"Object": THE ∧ (BOOK ∨ WALL ∨ ARTICLE)
"Event": THE ∧ (LECTURE ∨ SPEECH)

Table 25
Coverage structure CS_{OBJ} for processing 'the author began the book'

the	*author*	*began*	*the*	*book*	
the	*author*				*AG_{CO1}/ANIMATE*
		began	***the***	***book***	**AG_{CO2}**
			the	*book*	*AG_{CO1}/OBJECT*

Table 26
Coverage structure CS_{EVENT} for processing 'the author began the book/lecture'

the	*author*	*began*	*the*	*lecture*	
the	*author*				*AG_{CO1}/ANIMATE*
		began	***the***	***lecture***	**AG_{CO2}**
			the	*lecture*	*AG_{CO1}/EVENT*

Thus, the degree of similarity of the CSs of the primes to the CS of a coerced target – CS_{OBJ} > CS_{EVENT} > CS_{CO1}, where CS_{OBJ} is the most similar – mirrors their suitability for priming coerced utterances, in concert with the experimental results.

Raffray et al. (2014) found a boost to priming when prime and target shared the coerced, but overtly unexpressed, verb. For instance, *The celebrity began the champagne* constituted a stronger prime for *The banker began the tea* than *The caretaker began the stairs* did, which suggests that the underlying coerced verb '*drink'* establishes a stronger connection between '*champagne'* and '*tea'* than the connection between '*stairs'* and '*tea'*. Assuming more fine-grained concepts than in (17), we could also classify objects according to the verbs they can be associated with. For example, concept "*Object to be written*", basically definable for AG_{CO1} as THE ∧ (BOOK ∨ ARTICLE), could specify those utterances, that are most closely related to the verb '*write*'.

The circuitry interpretation of the AG model additionally allows an account of semantic differences where CSs need not be explicitly differentiated conceptually. In Section 3.2 we related semantic priming effects to an interaction between AGs and conceptual circuits. A similar line of reasoning might be valid here, too. Just as *the sheep that is red* is primed more by *the goat that is red* than by *the knife that is red* (Cleland and Pickering, 2003), it can be possible that *began the wall* is primed more by *began the book* than by *began the lecture* because of shared underlying conceptual circuits. Supposing that BOOK and WALL are both part of a, say, OBJECT circuit would imply that activation from the BOOK concept could reach not only the *'book'* node of AG_{CO1} (and/or AG_{CO2}) through the lexical *'book'* node but also the *'wall'* node of AG_{CO1} since some activation from the Concept layer BOOK node can spread to the WALL node as they are conceptually connected within the OBJECT circuit, and this (weaker) activation can ultimately propagate to the

AG_{CO1} *'wall'* node. Although such incidental activation of *'wall'* can be backgrounded by the winner *'book'*, the residual activation of the corresponding *'wall'* pathway (alongside with the residual activation of the AG_{CO1} category nodes) facilitates easier accessibility of AG_{CO1} for a subsequent utterance fragment containing the word *'wall'*. Similarly, *began the tea* can be primed more strongly by *began the champagne* than by *began the stairs* if we assume that CHAMPAGNE and TEA belong to a shared conceptual circuit (DRINK) whilst they have no relevant conceptual links in common with concept STAIRS.

4.7. Closed-class elements

Investigating the role of closed-class morphemes, Pickering and Branigan (1998) found no effect on priming. Sentences (18) all primed *the doctor gave the medicine to the patient.*

(18)
the *teacher gave* the homework to the children
the *teacher gives* the homework to the children
the *teacher was giving* the homework to the children
the *teachers give* the homework to the children

It can be seen immediately that whereas the initial part of the utterances can differ with regards to grammatical features, the final sequences are fairly homogeneous. This suggests a partial matching of the respective CSs and a similar priming potential for all the primes in (18). For a particular analysis, consider the AGs in (19) and the CSs in Tables 27 – 30.

(19)

AG25	AG26	AG27	AG28
gives homework	medicine to children	teacher gives	teachers give
gives money	homework to children	doctor gives	doctors give
gives medicine	medicine to patients	teacher **gave**	teachers **gave**
gave homework	medicine to **patient**		
	AG29		
	teacher was giving		
	doctor was giving		

Indeed, all prime CSs share group AG26 with the target CS. Furthermore, CS_{PRIME1} is identical with the target CS. CS_{PRIME2} has AG26 and the same number of words as the target. CS_{PRIME3} still has AG26 but it requires the extra word '*was*'. Assuming, again, that the degree of similarity of the CSs of the primes to the target CS mirrors the intensity of the priming effect, we would predict the following ordering: $CS_{PRIME1} > CS_{PRIME2} > CS_{PRIME3}$, where CS_{PRIME1} primes most. It might be insightful to experimentally investigate whether there really are such fine-grained quantitative differences between the CSs in questions. Specifically, as CS_{PRIME3} may coverage-structurally be reminiscent of the passive construction, some subtle priming effect might be expected from e.g. *the doctor was giving medicine (to the patient)* for e.g. *the teacher was given access (to the children)*. Cf. also the discussion on reconstruction in Section 5.

Table 27
Coverage structure CS_{TARGET} for target 'doctor gave medicine to patient'

doctor	*gave*	*medicine*	*to*	*patient*	
doctor	gave				AG27
	gave	medicine			AG25
		medicine	to	patient	AG26

Table 28
Coverage structure CS_{PRIME1} for prime 'teacher gives homework to children'

teacher	*gives*	*homework*	*to*	*children*	
teacher	gives				AG27
	gives	homework			AG25
		homework	to	children	AG26

Table 29
Coverage structure CS_{PRIME2} for prime 'teachers give homework to children'

teachers	*give*	*homework*	*to*	*children*	
teachers	give				AG28
		homework	to	children	AG26

Table 30
Coverage structure CS_{PRIME3} for prime 'teacher was giving homework to children'

teacher	*was*	*giving*	*homework*	*to*	*children*	
teacher	was	giving				AG29
			homework	to	children	AG26

Note, that the example AGs in (19) are morphologically rather heterogeneous. For instance, *gives* and *gave* in AG25 conflate tense features (present vs. past). By employing more homogeneous AGs or, alternatively, sub-AGs representing "morphological/grammatical concepts", we could obtain different analyses, possibly with different CS. Nevertheless, all CS alternatives would result in some degree of priming since all of them should be suitable for mapping similarly the final part of the sentence, represented by AG26 in the present example.

Here we make the additional claim that further explanatory horizons can open up if we consider possible parallelisms between morphological and syntactic mapping. AGs could consist of combinations of sublexical components (viz. word stems and affixes) that could, in turn, be combined into CSs. For a very simplified English example consider the AGs in (20) and CS_M in Table 31 for the morphological processing of 3rd–singular verb form *'reuses'*.[9] In principle, repeated use of morphological AGs and CSs might also contribute to priming.

[9] See Section 5.1 in Drienkó (2020b) for some Hungarian examples.

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(20)

AG_{M1}		AG_{M2}	
dis	close	close	d
dis	use	use	d
re	close	move	d
		close	s

Table 31
Morphological coverage structure CS_M for mapping the word 'reuses'

re	*use*	*s*	
re	use		AG_{M1}
	use	s	AG_{M2}

5. Anomalous sentences and reconstruction

5.1. AG-level reconstruction

In experiments on the comprehension of anomalous sentences Ivanova, Pickering, Branigan, McLean, and Costa (2012) found that morphologically anomalous sentences like (21a), sentences with novel verbs like (21b), and inappropriately used intransitive verbs like (21c) all primed target picture descriptions.

(21)
a) The waitress *gived the book to the monk
b) The waitress brunks the book to the monk
c) The waitress exists the book to the monk

It was demonstrated in Drienkó (2014) how an extended mapping mechanism can enhance the processing capacity of AGs by "guessing" the AG-category of unknown words, i.e. by allowing mapping of novel word w_i of utterance u_k onto a suitable position in AG_n if all the other words of u_k can be mapped onto their proper positions in AG_n. For instance, *baby brunks tea* can be mapped onto AG15 by assuming the same agreement category (position in the AG) for *'brunks'* as for *'brings'* and *'gives'*. Thus, e.g. *baby brunks tea to mommy* can prime *mommy gives bread to baby,* cf. Tables 11, 32 and (22).[10]

[10] In a circuitry setting, extended mapping (reconstruction) might be realised explicitly via a "?" lexical node connected to all AG nodes. When no appropriate concept-lemma-AG route can be found between conceptual, lexical, and AG nodes, an "UNKNOWN/NOISE" concept could activate the "?" lemma, which in turn could raise the activation level of all the AG nodes by sending activation, thereby enabling full activation of otherwise incompletely evoked AGs. This alone means more extensive activation for mapping. Furthermore, since some AG nodes have already been activated by their proper lemmas, these nodes may receive even stronger activation producing a more enhanced priming potential for the reconstruction mechanism. Cf. the discussion of inverse frequency effect in Section 5.4.

Table 32

CS_{POD} for 'baby brunks tea to mommy'

baby	*brunks*	*tea*	*to*	*mommy*	
baby	?brunks	tea			?AG15
			to	mommy	AG16

(22)

AG15	AG16	AG17
<u>baby brings tea</u>	<u>to mommy</u>	<u>gives mommy tea</u>
baby gives tea	to daddy	brings mommy tea
baby brings bread	for mommy	gives mommy juice
mommy brings tea	with mommy	gives daddy tea
baby brings juice	to baby	
AG48	AG49	
<u>we give tea</u>	<u>give mommy milk</u>	
you give tea	give mommy tea	
I give tea	bring mommy milk	
we bring tea		
they give tea		
we give bread		

Note that due to CS-similarity, some priming effect from anomalous sentences can be expected even without reconstruction. Since all the ill-formed sentences in (21a)-(21c) share a well-formed prepositional end fragment, they can be expected to prime POD targets even if no "correct" CS can be constructed or found for such anomalous utterances. This is supported by research on garden-path sentences, e.g. by Van Gompel, Pickering, Pearson, and Jacob (2006) who found that incorrect analyses can retain activation and, thus, produce priming effects.

The "guessing" mechanism can also be activated for sentences like (21c) if incorrectly used words are interpreted as novel i.e. as having a novel meaning. By extended mapping of '*exists'* onto AG15, for instance, the word can be understood as meaning something like '*brings'* or '*gives*' and utterance *baby exists tea to mommy* would be mappable. Similar arguments may hold for *baby *gived tea to mommy* containing the incorrect verb form **gived,* also contained in (21a), with the difference that, in AG15, '*gives'* could have priority over '*brings'* due to some activation from the lexical '*give'* node. Furthermore, if AG15 contained the past-tense verb form '*gave'*, the reconstruction of '*gave'* for **gived* could receive additional support (i.e. more than '*gives*') from the past-tense lexical node *'gave'* possibly activated by concept PAST as a result of detecting suffix '-ed' in **gived.*

When the guessing mechanism is activated, it is practically irrelevant what particular phonological form a nonce word has: substituting e.g. *x, zagsg*, or ##### for *brunks* in (21b) could similarly licence mapping onto AG15. In the ultimate case, the nonce word has no phonological form at all, like in sentence **The waitress the book to the monk* containing no verb. Since this sentence still retains the prepositional ending *to the monk,* it suggests a priming bias for POD. With additional help from the AG guessing mechanism, the mapping

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system might ultimately "reconstruct" an optimal CS for such an utterance by selecting or activating, among possibly many others, the most suitable AGs. Figure 6 sketches the situation where groups AG15 and AG16 have been activated for **baby tea to mommy* and the two groups can be combined into CS_{POD} with the proviso that something is missing between the first two words. Our analysis also accords with the results in Ivanova, Branigan, McLean, Costa and Pickering (2017) who claim that comprehenders can reconstruct the constituent structure of anomalous sentences since anomalous sentences with missing verbs primed participants' picture description utterances as much as well-formed sentences did.

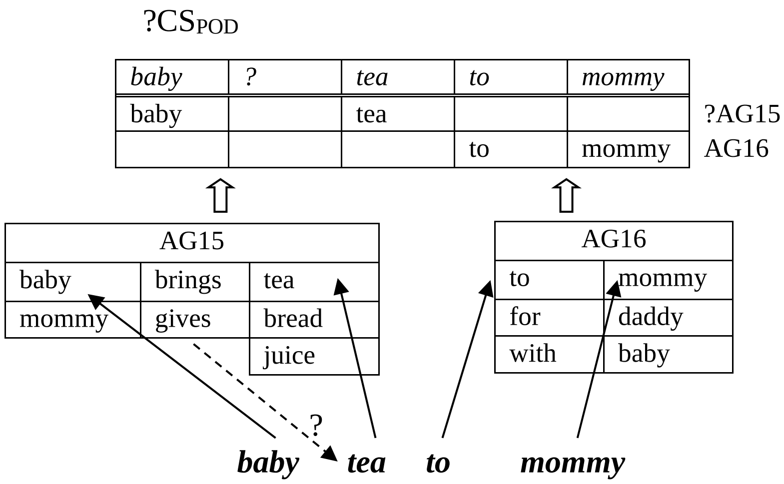

Figure 6. Reconstructing CS_{POD} for **baby tea to mommy*

5.2. CS-level reconstruction

Besides the AG-level guessing mechanism invoked above for identifying AG member candidates in order to handle the anomalous utterances in the examples (21a-c), there might be a CS-level guessing component responsible for providing the missing AGs for underspecified CSs. On hearing, for instance, the utterance pair *we give mommy tea, he doesn't*, speakers of English will trivially understand the second utterance as *he doesn't give mommy tea* which suggests the interpretation that speakers may use AGs activated for the CS of a previous utterance (fragment) – together with the actual words mapped onto them – to guess the missing AG(s) for the current utterance (fragment). Tables 33 and 34 show how AG49, as reconstructed from CS_1, the CS for *we give mommy tea*, can be combined with an AG for *he doesn't*, e.g. AG30, to yield the reconstructed CS_2 where the deleted part should be understood as having no explicit phonological manifestation in the utterance. Cf. AGs (22).

Table 33
CS_1 for 'we give mommy tea'

we	*give*	*mommy*	*tea*	
we	give		*tea*	AG48
	give	mommy	tea	AG49

Table 34
CS_2 for 'he doesn't give mommy tea'

he	*doesn't*	~~*give*~~	~~*mommy*~~	~~*tea*~~	
he	doesn't				AG30
		~~give~~	~~mommy~~	~~tea~~	~~(AG49)~~

With *she gives mommy tea, he doesn't*, the situation is a bit more complex since *gives mommy tea* requires AG17, so this fragment could only be mapped onto AG49 via reconstruction, assuming that '*gives'* is something like '*give'*, which assumption could be supported by activation from the lexical '*give'* node. Here we see an example of reconstruction on two levels: the CS-level reconstruction of AG49 for CS_2 is dependent on the AG-level reconstruction of the appropriate verb form '*give'* for '*gives'* as prescribed by AG49.

5.3. Activation intensity and reconstruction levels

Experimental research seems to suggest that the reconstruction of missing components requires varying degrees of activation, depending on the level of structural inference. AGs involved in the extended mapping of unfamiliar words (e.g. AG15 for *baby ? tea*) seem to be more strongly activated (stay longer in memory) than reconstructed AGs for CSs (e.g. AG49 for CS_2). Cai, Pickering, Wang, and Branigan (2015) showed that, in Mandarin, both full DOD utterances and DOD utterances with elided (missing) Theme NPs primed full DOD sentences, i.e. both (23a) and (23b) produced priming.

(23)

a) *Niuzai mai-le yiben shu hou* ***song-gei-le shuishou na ben shu***
(The cowboy bought a book and later **gave the sailor the book**)

b) *Niuzai mai-le yi ben shu hou* ***song-gei-le shuishou***
(The cowboy bought a book and later **gave the sailor** [that book])

It is logical to assume that the *gave (the) sailor (the) book* (*song-gei-le shuishou shu*) fragment of the sentence in (23a) can be mapped onto a single AG representing the DOD construction in question. By extended mapping, the *gave sailor* (*song-gei-le shuishou*) fragment of (23b) can likewise be mapped onto that AG, presuming a missing noun at the end. This missing noun, then, can be identified with the word *book (shu)* – as supported by previous activation of the corresponding lexical node for use in the first part of the sentence – and the AG in question can take part in the priming of subsequent utterances.[11]

On the other hand, Cai, Pickering, and Sturt (2013) found no priming with elided VPs. For instance, neither the DOD fragment *jie-gei shuishou na ba qiang* in (24a) nor the POD fragment *jie na ba qiang gei shuishou* in (24b), as assumed to be reconstructed for the *bu xiang* (*would not like to*) fragments in the corresponding target sentences, primed the respective dative constructions.

[11] Recall that the same utterance can be mapped onto several AGs, so, in general, the priming effect may rather be ascribed to the set of AGs that a given fragment is compatible with than just to a single AG.

(24)

a) *Fuwuyuan xiang* ***jie-gei shuishou na ba qiang***.
(The waitress would like **to lend the sailor the gun**)
*Yinwei haipa reshi chushi que bu xiang [**jie-gei shuishou na ba qiang**].*
(Because of fear of trouble, the chef would not like to [lend the sailor the gun])

b) *Fuwuyuan xiang* ***jie na ba qiang gei shuishou***.
(The waitress would like **to lend the gun to the sailor**)
*Yinwei haipa reshi chushi que bu xiang [**jie na ba qiang gei shuishou**].*
(Because of fear of trouble, the chef would not like to [lend the gun to the sailor])

The results suggest that the AG activated for the mapping of the '*lend sailor gun'* DOD sentence fragment in order to be combined with the AG for the '*would not like (bu xiang)'* fragment in the CS for the whole utterance is either not activated to a sufficient degree or is not kept in memory long enough to cause DOD priming effects with subsequent utterances. Similar arguments may hold for POD sentences (cf. *lend gun to sailor).* Thus, experimental findings suggest that AGs involved in the within-AG inference of missing words (e.g. '*book'* for '*gave sailor book')* may get stronger activation (persist longer in memory) than AGs reconstructed for missing AGs in CSs (e.g. than the AG for mapping '*lend sailor gun'* as in the case of '*would not like to [lend sailor gun]'*). This discrepancy is also mirrored in the coverage properties of the phenomenon: the reconstructed AG (for '*lend sailor gun'*) does not explicitly appear in the CS of the priming sentence (*Because of fear of trouble, the chef would not like to)* whilst the AG for '*gave sailor book'* is actually represented in the CS of the prime *(The cowboy bought a book and later gave the sailor)* even though the object noun (*book*) is not expressed overtly. Tables 35–38 contrast the various priming conditions visually. Table 35 sketches the relevant structure, CS_{CH1}, for the Chinese DOD construction. Table 36 shows that CS_{CH1R} can similarly facilitate priming subsequent DOD utterances because AG_{CHDOD} is explicitly activated and the missing noun (*shu*) is reconstructed. Table 37 outlines CS_{CH2}, the Chinese DOD construction for the missing VP case. As Table 38 demonstrates, CS_{CH2R} cannot result in priming because AG_{CHDOD} is not explicitly contained (is not activated strongly enough) in CS_{CH2R}.[12]

[12] Arguably, it might not be necessary to distinguish between the two options, DOD or POD, for the missing VP to process the same message when the message is not fully articulated. Indeed, the two constructions are conceptually equivalent and they activate exactly the same lexical nodes (with different word-order). When the speaker is forced to process, i.e. to choose, one particular construction, it can naturally be biased by previous use and it can bias subsequent use. However, when no choice is necessary, i.e. an utterance component is not represented explicitly in the CS, due to this uncertainty, no priming should be expected from the utterance component in question.

Table 35

CS_{CH1} for Chinese DOD construction (NP ellipsis experiment)

Niuzai	*mai-le*	*shu*	*hou*	*gei-le*	*shuishou*	*shu*	
Niuzai	mai-le	shu					
	mai-le	shu	hou				
				gei-le	shuishou	shu	**AG_{CHDOD}**

Table 36

CS_{CH1R} with reconstructed word 'shu'

Niuzai	*mai-le*	*shu*	*hou*	*gei-le*	*shuishou*	~~*shu*~~	
Niuzai	mai-le	shu					
	mai-le	shu	hou				
				gei-le	shuishou	~~shu~~	**AG_{CHDOD}**

Table 37

CS_{CH2} for Chinese DOD construction (VP ellipsis experiment)

Fuwuyuan	*xiang*	*jie-gei*	*shuishou*	*qiang*	
Fuwuyuan	xiang				
		jie-gei	shuishou	qiang	**AG_{CHDOD}**

Table 38

CS_{CH2R} with reconstructed AG_{CHDOD}

chushi	*bu*	*xiang*	~~*jie-gei*~~	~~*shuishou*~~	~~*qiang*~~	
chushi		xiang				
	bu	xiang				
			~~jie-gei~~	~~shuishou~~	~~qiang~~	~~**AG_{CHDOD}**~~

5.4. Reconstruction and the inverse frequency effect

The extended mapping mechanism (reconstruction) might also underlie the "inverse frequency/preference" effect, i.e. the observation that longer-term priming is stronger when the prime construction is less frequent (e.g. Pickering and Ferreira, 2008). "Less frequent" constructions are synonymous with "represented by fewer and/or smaller AGs" in our model. This increases the probability that a given rare-construction utterance (fragment) cannot be mapped onto an appropriate AG directly. Reconstruction can be useful here, too. Suppose, for example, that the English passive voice is less frequent than the active construction and we have AGs like in (25). On attempting to process e.g. '*milk is drunk*', the mapping system detects the lack of any suitable AGs and can call on the reconstruction mechanism. Checking all (the two) candidate AGs, the system can conclude that mapping '*milk? is drunk*' onto AG_{P1} is viable if '*milk*' belongs to AG-category {*water, tea*} or, alternatively, '*milk is? drunk*' can be mapped onto AG_{P2} if '*is*' is something similar to '*was*'. The decision as to which AG to choose may be based on semantic information from the Concept layer. As '*is*' is typically associated with concept PRESENT while '*was*' with PAST, AG_{P2} does not seem to be a fair option. In contrast, MILK can be strongly linked to other beverages, inter alia to WATER and TEA, in a semantic circuit of the Concept layer which biases AG_{P1} as the right option.

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(25)

AG_{P1}	AG_{P2}
water is drunk	coffee was drunk
tea is drunk	milk was drunk
	beer was drunk

Since the reconstruction process requires an extensive search (activation) of pathways, it can ultimately involve large node populations, possibly larger than for mapping without reconstruction for the more common and larger AGs. Recall that we associate a higher probability of long-lasting activation with larger node populations, hence we expect a higher priming potential for less frequent constructions requiring reconstruction via extended mapping (cf. footnotes 5 and 8).

Stronger activation for novel utterances may additionally have a within-AG dimension. Whereas memorised AG-member utterances can be accessed more directly, possibly bypassing category nodes, novel utterances require the category nodes for previously unconnected words to be connected, cf. Figures 1 – 3. Consequently, the mapping of novel utterances requires longer pathways, involving more nodes and connections which, again, can entail longer and/or stronger activation and priming potential. Since rare constructions can reasonably be supposed to require more novel word combinations than frequent ones, within-AG variability is an additional source of enhanced priming for less frequent constructions. Note that within-AG variability is graded in proportion to how many category nodes can be bypassed. Thus, for instance, '*mommy brings tea'* is a member utterance of AG15 in (13) and can be mapped without intervening category nodes, '*mommy gives tea'* can bypass one category node (between '*gives*' and '*tea*', i.e. activation can propagate directly from '*gives'* to '*tea'* since the '*gives tea*' fragment is a part of the member utterance '*baby gives tea*'), and finally, *mommy gives juice* requires all the category nodes of AG15, i.e. the longest pathway. Further degrees of novelty, as with e.g. '*mommy gives brunk'* will be handled by the reconstruction mechanism.

5.5. Code-switching and reconstruction

In speakers of English with no knowledge of Hungarian, sentences '*baby brunks tea to mommy* 'and '*baby hoz tea to mommy'* would be processed similarly. However, for English-Hungarian bilinguals, this could be an instance of code-switching since '*hoz*' means '*brings*' in Hungarian. Consequently, code-switching seems to be related to reconstruction. Indeed, fragment '*baby hoz tea'* can be mapped onto AG15 only by inference, i.e. assigning AG-category {*gives, bring*} to '*hoz*'. This category assignment and a strong bias for AG node '*brings*' can be supported by activation either via direct English-Hungarian connections between nodes '*bring/brings*' and '*hoz*' in the Lexical layer and/or via concept BRING as connected to both the English '*bring*' and the Hungarian '*hoz*' lemmas. Mapping '*hoz*' onto AG15, in turn, enables the activation (and possible re-activation for priming subsequent utterances) of CS_{POD}, shown as CS_{PODR} by Table 39. Cf. also Figure 5.

Table 39

Reconstructed CS_{PODR} for 'baby hoz tea to mommy'

baby	*hoz*	*tea*	*to*	*mommy*	
baby	?hoz	tea			?AG15
			to	mommy	AG16

Note that this account agrees with what was said about code-switching in Section 3.3. From a reconstruction aspect, however, it can be a question whether the reconstruction apparatus is needed in its entirety (searching through all possible AGs as required by an "UNKNOWN/NOISE" concept) with support from cross-linguistic connections, or supporting activation via cross-linguistic connections alone could suffice to identify the needed word/AG. The answer could arise from experiments with anomalous utterances containing both true nonce words and nonce words that are actually meaningful in another language. We may expect a difference in priming effects for bilinguals. Priming should be smaller for meaningful nonce words if they can be identified through cross-linguistic connections. On the other hand, if priming is the same or larger than for true nonce words, it could mean that the whole reconstruction apparatus is deployed possibly involving a much larger node population. Additionally, measuring bilinguals' processing times in experiments with the two types of anomaly might also be informative about the degree of reconstruction involved.[13]

6. Developmental aspects of priming

The present section aims to highlight the developmental aspects of the AG framework against the backdrop of a representative selection of observations from experiments with various age groups. First we list the major findings then demonstrate how they are compatible with the AG model.

6.1. Developmental findings

Rowland, Chang, Ambridge, Pine, and Lieven (2012) investigated the developmental aspects of linguistic priming by conducting experiments with 3-4 year olds, 5-6 year olds, and adults. The participants were primed with double object dative (DOD) and prepositional dative (POD) sentences. The authors found i) that structural priming occurred in all age groups: 3-4 year olds, 5-6 year olds, and adults; ii) some evidence that structural priming was larger in the younger child group than with older children and adults; iii) that children, especially 3-4 year olds, produced fewer DODs than adults; iv) a significant increase in priming effect when prime and target sentence shared the same verb (lexical boost) in adults, a small increase with older children, and no increase in the youngest child group. Buckle, Lieven, and Theakston (2017) examined to what extent animacy-semantic role mappings in POD and DOD prime and target sentences influenced the choice of syntactic structure and post-verbal noun order in children (3- and 5-year-olds) and adults. They

[13] An even more intriguing question could be the case of anomalous words having different meanings in different languages. In e.g. *Baby ad tea to mommy*, '*ad*' can either be interpreted (in various ways) as an anomalously used English word or as the Hungarian word for '*gives*'. The interpretation may depend on the previously/simultaneously activated lexical, semantic or AG nodes.

found that v) structural priming occurred in all age groups; vi) animacy could moderate the magnitude of structural priming in only 3-year-olds; vii) 5-year-olds and adults produced more DODs for prototypical (animate goal, inanimate theme) targets; viii) noun animacy primed the ordering of nouns in children (3- and 5-year-olds); ix) noun animacy did not prime the ordering of nouns in adults. Table 40 summarises the observations.

Table 40
Observations in developmental research

<table>
<tr><td>i)</td><td>Structural priming in all age groups: 3-4 year olds, 5-6 year olds, and adults</td><td rowspan="4">Rowland et al. (2012):
3-4 year olds, 5-6 year olds, and adults,
DOD, POD</td></tr>
<tr><td>ii)</td><td>Structural priming larger in the younger child group than with older children and adults</td></tr>
<tr><td>iii)</td><td>Children, especially 3-4 year olds, produce fewer DODs than adults</td></tr>
<tr><td>iv)</td><td>A significant lexical boost in adults, a small boost with older children, and no boost in the youngest children</td></tr>
<tr><td>v)</td><td>Structural priming in all age groups</td><td rowspan="5">Buckle et al. (2017):
3-year-olds,
5-year-olds,
adults,
DOD, POD,
animacy-semantic role mappings</td></tr>
<tr><td>vi)</td><td>Animacy moderates structural priming in 3-year-olds</td></tr>
<tr><td>vii)</td><td>5-year-olds and adults produce more DODs for prototypical (animate goal, inanimate theme) targets</td></tr>
<tr><td>viii)</td><td>Noun animacy ordering priming effect in children (3- and 5-year-olds)</td></tr>
<tr><td>ix)</td><td>No noun animacy ordering priming effect in adults</td></tr>
</table>

Overall, the results seem to accord with the U-shaped AG homogenisation trajectory observed in Drienkó (2017; 2020a; 2020b, Section 4.5) We assume that, initially, there is a general expansion of the AG space, with AGs rather mixed with regards to various linguistic categories. Then at some point of development, they begin to become more specific (homogeneous), corresponding more closely to some particular aspects of language. At this point a reduction might be observed in some processing capacities. Then, the AG space, with its homogenised groups, starts to expand again and processing improves. Note that re-expanding AGs, homogenised in terms of a particular linguistic category (e.g. verb types) may become increasingly more heterogeneous in terms of other aspects of language (e.g. the type of nouns that may co-occur with a particular verb type). What follows is a discussion of how specific details of the experimental findings can be integrated into this more general picture of linguistic development envisaged by the AG framework. Roman numbers refer to the observations in Table 40.

6.2. Structural priming is larger in (younger) children: i), ii), v)

The observed structural priming in 3-4-olds reveals that repeated usage of AGs is possible from a very early age (i, v). Besides, at the early stages of development, AGs are less homogenised – giving rise to various possible speech errors – so the same AG can be accessed through a larger variety of words which means a greater probability for subsequent utterances to be mapped onto the same AG, i.e. a greater likelihood of structural priming (ii).

Additionally, AGs are not only inhomogeneous but there are fewer of them at the earlier developmental stages which also increases the probability of repeated usage (ii). Arguably, with less developed linguistic capacity, children may need to resort to reconstruction mechanisms to a larger extent than adults. Reconstruction, as we proposed earlier, can potentiate larger AG populations entailing an enhancement of priming (ii).

6.3. Lexical boost in adults: iv)

The above claim that the fewer and less homogeneous AGs in early development can be accessed through a larger variety of words, in general, also suggests that a greater number of more homogeneous AGs at later stages increase the probability that the same AG will be accessible through a possibly smaller variety of words, compatible with some specific linguistic category, e.g. GIVE/TRANSFER. On the other hand, once this category has been identified (by a compatible word in a previous sentence) in a concrete AG, there will be a greater chance for other words (e.g. nouns as direct or indirect object candidates for '*give*') in a subsequent utterance to be included in (i.e. to be mappable onto) the same AG (out of possibly several alternative AGs) because adult AGs integrate a more heterogeneous collection of nouns compatible with GIVE. For example, while '*give mommy tea'* may boost '*give employee salary'* lexically via a shared underlying AG in adults, it is less likely in the case of young children. In other words, a child's AG32 in (26), e.g., may not include the words *'employee'* or *'salary'* but later on they can appear in their appropriate AGs. In the circuitry interpretation, the lexical node (*give*) together with the corresponding AG nodes, as well as the concomitant links between the nodes, constitute a more robust processing bias, lexical boost, for subsequent utterances in mature speakers, cf. Sections 3.2. and 6.4.

6.4. Children produce fewer DODs than adults: iii)

The results may reflect the evolution of alternative linguistic constructions via the maturation process of the AG mapping system. Initially, (two-word) AGs are mixed with respect to semantic roles, allowing both goals and themes to be mapped onto them. For example, utterances *give tea(theme),* and *give baby(goal)* can be mapped onto AG32 in (26). There are no/few AG combinations at this stage. Later on, as group combinations for CSs begin to emerge, it becomes possible to express the difference between goal and theme syntactically. The key component in doing so must be the formation of appropriate AGs. By homogenising AG32 into AG33 to comprise prototypical theme nouns and forming prepositional AGs like AG34 for prototypical goals, the mapping system can combine them into CSs to represent (prototypical) prepositional dative constructions like *give milk to mommy*, cf. (26) and CS_{POD} in Table 41.

(26)

AG32	AG33(theme)	AG34(goal)
give tea	give tea	to mommy
give milk	give milk	to baby
give mommy	~~give mommy~~	to daddy
give baby	~~give baby~~	
take tea	take tea	
bring tea	bring tea	
provide tea	provide tea	

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Table 41
CS_{POD} for POD constructions

give	*milk*	*to*	*mommy*	
give	milk			AG33
		to	mommy	AG34

Another way to assign semantic roles, without the intervention of prepositions, is via word- order. Combining AG32 with itself yields a verb-noun-noun sequence. If learners realise that the first noun is always the goal and the second is the theme (e.g. *give mommy milk)* they can use this information to encode the thematic roles into the corresponding CS. As the DOD structure CS_{DOD} in Table 42 reveals, the noun in the continuous fragment mapped onto AG32 corresponds to the goal, whereas the noun of the discontinuously used AG32 represents the theme. Alternatively, the verb-goal-theme order can be encoded into AGs in the first place. After the developmental stage of two-word combinations, the DOD construction can be represented by memorised three-word-long utterances, and their corresponding AGs, cf. AG_{DOD1} in (27). The finding that children produce fewer DODs than adults suggests that CS_{POD} emerges sooner than CS_{DOD} or DOD AGs.[14]

Table 42
CS_{DOD} for DOD constructions

give	*mommy*	*milk*	
give	mommy		AG32(continuous)
give		milk	AG32(discontinuous)

(27)

AG_{DOD1}
<u>give mommy tea</u>
give mommy milk
give mommy dolly
give baby tea
give daddy tea
bring mommy tea

The assumption that both the POD and the DOD construction derive from a "common ancestor" (e.g. like AG32) is supported by the observation in Goldwater, Tomlinson, Echols, and Love (2011) who found that in scene description tasks the prime in one type of dative (DOD or POD) increased the likelihood of using both dative types in 4-year-olds This suggests that although children can already combine AGs to build CSs for both dative types, the two types do not fully differentiate by the age of 4 (e.g. because AG32 is not homogeneous enough, so it can be employed for both CS_{POD} and CS_{DOD}).

[14] The POD construction can also be represented by dedicated AGs. However, they should minimally consist of four words (verb, theme, preposition, goal) so they can emerge (similarly to DOD AGs) after the two-word combination stage.

The common ancestor idea is also in line with findings in Hare and Goldberg (1999) who report that *provide-with* sentences (e.g. *The officers provided the soldiers with guns*) behaved like double-object (DOD) primes. As Table 43 illustrates, *provide-with* sentences are structurally fairly similar to DOD constructions. Both CS4 in Table 43 and CS_{DOD} in Table 42 employ AG32 in the same way (i.e. continuously for the goal noun and discontinuously for the theme), with the difference that CS4 additionally involves AG35 that prescribes preposition '*with*' for *provide*-type verbs, cf. (28).

Table 43

CS4 for provide-with type constructions

provide	*mommy*	*with*	*milk*	
provide	mommy			AG32(continuous)
provide			milk	AG32(discontinuous)
provide		with	milk	AG35

(28)

AG35
<u>provide with food</u>
provide with milk
supply with food

6.5. Animacy moderates structural priming in only 3-year-olds, not in 5-year-olds and adults: vi)

At a very early age, when there are rudimentary, prototypical POD CSs – e.g. CS_{POD} in Table 41 – and there are even less developed or no AGs for the DOD construction – e.g. AG_{DOD1} in (27) with animate goal and inanimate theme – the processing of non-prototypical utterances may be more difficult. This processing difficulty can be reflected in priming. When a non-prototypical utterance is processed, the failure to identify a suitable (unequivocal) CS for it naturally results in a lack of priming for a subsequent utterance, since priming would require the repeated use of the previously identified CS. Quantitatively, this could imply that structural priming in young children would decrease in proportion to the number of non-prototypical primes. Reconstruction success or, rather, failure may also contribute to the modulatory effect of animacy as younger children, with less developed linguistic capacity, may need to rely on the reconstruction mechanisms more than older speakers do. Since reconstruction activates larger AG populations, it facilitates structural priming (cf. ii). However, when even reconstruction fails to find tentative AG/CS candidates for non-prototypical constructions due to the rudimentary stage of the AG system, no priming should be expected.

6.6. Noun animacy ordering priming effect in children (3- and 5-year-olds): viii)

Why animacy can prime the ordering of nouns irrespective of the dative type (POD or DOD) might be explained with the existence of more heterogeneous or general AGs at early developmental stages plus concepts that can mark out sub-domains within AGs. For example, the animate-inanimate dichotomy in the unhomogenised AG32 is mirrored by concepts

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"Transfer animate" and "Transfer inanimate", as (29) shows. Thus the same, conceptually differentiated, group, AG32, can be activated for both the POD and the DOD construction. Tables 44 and 45 illustrate how the respective CSs are similar owing to the conceptually specified shared sub-AG that is needed for the first part of the utterances. As a result, the POD sentence '*give baby to tea*', with the animate theme '*baby*', can cause some priming for the DOD '*give mommy milk*' containing the animate goal '*mommy*'. In both sentences an animate noun is followed by an inanimate one, whereas the semantic role orders are reversed (theme-goal vs. goal-theme). Essentially, our argumentation would be the same for '*give tea to baby*', with the inanimate theme '*tea*', and '*give milk mommy*', with the inanimate goal '*milk*'. However, in this case, priming would come from the conceptual domain AG32/INANIMATE rather than AG32/ANIMATE in the corresponding CSs. The present analysis suggests animacy priming for the first post-verbal nouns. Whether or not there is priming between the second nouns, as well, could be determined experimentally. Under our present interpretation, no priming between the second nouns would be anticipated.

Note, that without conceptual sub-domains, AG32 could be used more freely, for both POD and DOD, irrespective of animacy features. Such a situation would be reminiscent of the observation in Goldwater et al. (2011), that the two dative types can prime each other, since AG32 would be comprised both in Table 44 and in Table 45 without conceptual restrictions. Again, we conclude that at around the age of 4, the two types of dative are not yet fully differentiated, cf. Section 6.4.

(29)

AG32	
give tea	CONCEPT "Transfer Animate":
give milk	(GIVE ∨ TAKE ∨ BRING ∨ PROVIDE) ∧ (MOMMY ∨ BABY))
give mommy	
give baby	
take tea	CONCEPT "Transfer Inanimate":
bring tea	(GIVE ∨ TAKE ∨ BRING ∨ PROVIDE) ∧ (TEA ∨ MILK))
provide tea	

Table 44
Conceptually differentiated CS for POD constructions

give	*baby*	*to*	*tea*	
give	*baby*			*AG32/ANIMATE*
		to	*tea*	

Table 45
Conceptually differentiated CS for DOD constructions

give	*mommy*	*milk*	
give	mommy		AG32/ANIMATE
give		milk	AG32/INANIMATE

6.7. No noun animacy ordering priming effect in adults: ix)

The reason why adult processing is less conceptually-driven might be that the restructured (homogenised) and re-expanded AG space offers specific DOD AGs for processing DOD utterances rather than more general (heterogeneous) AGs for combining them into DOD CSs. The POD construction can likewise be supported by specific POD AGs in adults. Such a dissociation of grammatical construction types, in turn, is less likely to allow specific AGs for one construction type to be usable for another. Consequently, no such AG can be found that it is contained both in a DOD CS and a POD CS and its conceptual sub-domains (e.g. with respect to animacy) can facilitate cross-constructional conceptual priming. In other words, the emergence of more specialised AGs in older speakers reduces the structural overlap between POD and DOD.

6.8. 5-year-olds and adults produce more DODs for prototypical (animate goal, inanimate theme) targets: vii)

The explanation may reflect the way words are distributed across utterances or, for that matter, how words and/or utterances are distributed across AGs. The distribution of post-verbal nouns in DOD AGs can be such that AGs with prototypical word-order (i.e. animate goal, inanimate theme) are larger, providing a greater chance for animate-inanimate DOD AGs to be used for processing. This difference is specifically pronounced in older speakers because young children have fewer (and smaller) DOD AGs, or fewer (and smaller) AGs in general. How the distribution of post-verbal noun order across AGs can influence their processing potential is illustrated by the simplified example of (30). The largest group AG_{AI}, with prototypical animate-inanimate word-order, licenses $1{\times}4{\times}4=16$ DOD utterances. The non-prototypical inanimate-animate utterances are distributed across two distinct smaller AGs, AG_{IA1} and AG_{IA2} that yield $(1{\times}2{\times}2) + (1{\times}2{\times}2) = 8$ non-prototypical DOD utterances altogether. Thus the 16 possible prototypical animate-inanimate utterances, as opposed to the 8 inanimate-animate possibilities, implies a greater chance for a message with animate goal and inanimate theme to be processed by a DOD AG than a message with inanimate goal and animate theme. Since each utterance has its own group, supposing that the AG system is based on the 13 memorised utterances given in (30) would entail the existence of 7 prototypical, and larger, AGs (cf. the utterances in AG_{AI}), as well as 6 non-prototypical, and smaller, AGs (cf. the utterances in AG_{IA1} and AG_{IA2}), in accordance with the assumption that the prototypical DOD construction is represented by more and larger AGs.

(30)

AG_{AI} (prototypical)	AG_{IA1} (non-prototypical)	AG_{IA2} (non-prototypical)
<u>give mommy water</u>	<u>give zoo tiger</u>	<u>give house puppy</u>
give mommy milk	give zoo monkey	give car puppy
give mommy dolly	give garden tiger	give house kitten
give baby water		
give daddy water		
give mommy biscuit		
give granny water		

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The influence of across-AG word-type distribution on structural processing bias further seems to be highlighted by findings in Bidgood, Pine, Rowland, and Ambridge (2020), who emphasise that syntax is abstract and semantically constrained at the same time. Specifically, they find that the processing of the passive construction is semantically constrained both in 4-6 year olds and adults since participants in either age group produced significantly fewer passives for experiencer-theme verbs (ET, e.g. '*see*') than for agent-patient (AP, e.g. '*hit*') and theme-experiencer (TE, e.g. '*frighten*') verbs. The rank order of passive production (TE>AP>ET) may reflect the composition of AGs with respect to verb types. For instance, verbs belonging to various semantic categories (e.g. TE, AP, ET) may be represented in groups according to their proportions across vocabulary/lexicon. There may be more and larger TE groups than AP and ET groups, and more and larger AP groups than ET groups (e.g. adjectival TE verbs can mingle with adjectives in AGs, cf. '*was frightened*' and '*was sad*'). More and larger groups, as we pointed out above, means a greater chance for an utterance (and also for a similar subsequent one) to be mapped onto. This idea that the data reflect an overall distribution of semantic categories is, additionally, supported by the fact that the rank order of the verb type categories with respect to passive production – viz. TE>AP> ET – is the same for active primes as for passive primes in both age groups (cf. e.g. Figure 3 in Bidgood et al., 2020). In other words, the relative proportion of passive sentences with respect to thematic category is the same in the primed and unprimed (i.e. primed for active) conditions, which, in turn, may be indicative of the underlying AG substrate with regards to the distribution of verb types across AGs, i.e. across AGs responsible for the processing of passive utterances, in particular. Here, again, the distributional difference might be more pronounced in older speakers because young children must have fewer (and smaller) AGs for passive.

6.9. Summary of AG accounts for developmental findings

Table 46 juxtaposes observations i)-ix) with their possible interpretation in the AG framework.

Table 46
Developmental observations explained

	Observation	AG interpretation
i) and v)	Structural priming in all age groups: 3-4 year olds, 5-6 year olds, and adults	Repeated usage of AGs is possible from a very early age
ii)	Structural priming is larger in younger children than in older children and adults	Fewer and more heterogeneous (unhomogenised) AGs in children, accessible through a larger variety of words, larger need for reconstruction
iii)	Children, especially 3-4 year olds, produce fewer DODs than adults	AGs/CSs supporting DOD emerge later in development

iv)	Lexical boost in adults, a small boost with older children, and no boost in young children	Re-expanded larger AGs in adults, homogenised with respect to some category or lexical item increase likelihood of repeated use of an AG (CS) triggered by the corresponding category/lexical item
vi)	Animacy moderates structural priming in 3-year-olds	Prototypical (animate goal, inanimate theme) AGs/CSs in 3-year olds plus reconstruction failure to find unequivocal CSs result in difficulty with non-prototypical utterances (reduced priming)
vii)	5-year-olds and adults produce more DODs for prototypical (animate goal, inanimate theme) targets	Distribution of word types across DOD AGs in older speakers supports animate goal, inanimate theme (no full-fledged DOD in young children, cf. iii)
viii)	Noun-animacy ordering priming effect in children (3- and 5-year-olds)	Heterogeneous/unhomogenised early AGs, plus conceptual domains defined over them
ix)	No noun-animacy ordering priming effect in adults	Specific (DOD) AGs in adults, less structural overlap between POD and DOD

7. Conclusions and future work

It was demonstrated that an AG circuitry approach to linguistic processing may prove to be a useful tool for a unified theoretical treatment of structural priming phenomena. Specifically, we illustrated how priming can be related to the repeated activation of linguistic processing units, notably AGs and CSs, and, ultimately, to various degrees of CS-similarity. The formation and activation of AG circuits was supported by such intrinsic components of the AG model as conceptual domains definable over AGs, the developmental dynamics of the AG space, and a reconstruction mechanism for identifying underspecified linguistic material. The circuitry setting for AGs was particularly insightful in explaining the difference between short-lived lexical boost and longer-term general structural priming as related to the activation of node populations and/or memory processes (viz. repetition suppression and enhancement), as well as in interpreting cross-linguistic priming results.

In the analyses we met various issues that require further experimental investigation. In connection with the structural similarity of various utterance components, we raised the question whether there could be priming between prepositional phrases in non-POD sentences (e.g. *Baby brings tea* ***with*** *mommy*) and POD constructions (e.g. *Baby brings tea* ***to/for*** *mommy*) as the analysis of the POD construction in Section 4.1 and the discussion of locative and agentive by-phrases in Section 4.3 would suggest. By the same token, given the similarity rank-order of CSs for morphologically related sentence variants in Section 4.7, we would anticipate some fine-grained difference in the priming potentials of the corresponding CSs, and additionally expect some facilitation between Past Progressive and Passive sentences, such as *the doctor was giving medicine to the patient* and *the teacher was given access to the children*. Discussing the possible connection between the reconstruction mechanism of the AG circuitry model and cross-linguistic priming in Section 5.5 it was unclear whether the reconstruction apparatus is needed in its entirety with support from cross-linguistic connections, or supporting activation via cross-linguistic connections alone could suffice to identify the necessary AGs. In experiments with anomalous utterances containing both true nonce words and nonce words that are meaningful in another language we might expect a difference in priming effects for bilinguals. Smaller priming for meaningful words would highlight the role of cross-linguistic links, otherwise the involvement of reconstruction would be underlined. The AG interpretation of the moderating effect of animacy on structural priming in young children in Section 6.5 would forecast a proportional relationship between the reduction in structural priming and the number of non-prototypical primes. The analysis of noun-animacy ordering priming effect in Section 6.6 predicts animacy priming only for the first post-verbal nouns. Whether or not there is priming between the second nouns, as well, could be determined experimentally.

Computational simulations of the circuitry version of the AG model might yield further empirical insights, too. For instance, by letting the search mechanism start looking for appropriate AGs for the current utterance in the sub-collection of appropriate AGs for the previous utterance, it could be tested what processing benefits (e.g. speed) that could mean for structurally similar utterances or how repeated words can enhance processing.

The AG model allows for recursive AG combination but it is as yet unclear how recursion should precisely be incorporated in the circuitry architecture, in particular. Recursively (i.e. repeatedly) activated nodes might need to be related to memory processes, possibly via explicit links to dedicated memory nodes.

Especially in connection with Hungarian data, we ignored topic-focus issues influencing word-order, as a deeper consideration might involve additional cognitive-linguistic components, which would complicate analyses beyond the scope of this study. By the same token, we did not deal with quantifier scope phenomena that would require a more detailed picture of cognitive-semantic modules. However, from the Lexical layer to the AG/CS layers, the structural properties of, e.g., sentence *Every girl loves a boy* would be the same for both interpretations (*each girl has a different lover* contra *all the girls love the same boy*). For an outline account of the semantic dichotomy we note that the two interpretations may reflect a difference in conceptual coupling strategies. While coupling every instantiation/activation of concept GIRL with a single activation of concept BOY can correspond to one interpretation (girls loving the same boy), another possible strategy could be to link each instantiation of GIRL to a matching instantiation of BOY (for girls loving different boys). The former case would be reminiscent of the cognitive "ALL-TO-ONE" strategy in e.g. Drienkó (2012) for checking agreement features in syntactic processing (between a noun and its possibly several modifying adjectives in inflected languages, for instance) while the latter case may be analogous to the default strategy "FIRST-TO-FIRST", coupling each occurrence of word-type A with an occurrence of word-type B in temporal order for checking agreement (e.g. for *I am, you are, and she is happy*). Thus, conceptual processes underlying quantifier scope interpretation might share a cognitive coupling mechanism with syntactic feature-checking. In an "abstract" AG framework no explicit feature-checking is required since grammaticality is achieved through AG combinability. On the other hand, the circuitry version of the model might benefit from a memory-related coupling mechanism, especially in controlling recursive mapping processes.

As it stands, however, the AG-circuitry framework, allowing for abstraction on the basis of appropriate grouping of memorised utterance exemplars, offers explanations for major syntactic priming phenomena which cannot be consistently interpreted within a single mainstream model. Self-priming is a consequence of the activation-based characteristic of the AG-circuitry model: nodes can be (re)activated both by system-internal and external stimuli. The inverse-frequency effect is connected to the model's reconstruction mechanism as activating node populations. The temporal difference between short-lived lexical boost and long-lived structural (abstract) priming is due to an interplay between the activation level of AG populations and memory processes.

Although the AG–circuitry model explains a wide variety of experimental data and can be improved in several ways, it remains to be seen whether it can stand the test of many more linguistic constructions of natural languages. While even rather complex constructions might be interpreted in the model, especially if equipped with memory-related coupling strategies or recursive AGs and CSs, it is unclear what construction types would possibly constitute critical challenges for the model.

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