CHAPTER TWO

DEVELOPING CONVERGENCE: TOWARDS AN INTEGRATED DEVELOPMENTAL MODEL OF LANGUAGE PROCESSING IN CHILDREN AND ADULTS

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1. Introduction

This paper presents arguments for the benefits of convergent theories of language representation and language processing in children and adults. I use the term *convergence* to encompass both the theoretical, methodological, and educational aspects of this enterprise. Theoretically, convergence boils down to the claim that linguistics should account for *both* grammar and processing; methodologically the claim entails considering a broader range of data in addition to acceptability data; educationally, it entails forming linguists within the broader scope of cognitive science and neuroscience.

The core of the paper deals with the theoretical and methodological points that support the benefits of convergence. I find it useful to adopt the theory neutral definitions of the International Classification of Disability Functioning and Health (World Health Organization 2001; WHO-ICF for short) to ground the claim within the broader context of all of the disciplines that study language and communication from different perspectives. I will introduce the ICF framework in section 1.2 and situate the contributions of basic research in linguistics and psycholinguistics with reference to ICF domains. Section 2 outlines some open areas of inquiry at the interface between linguistics and psycholinguistics, organized around three general questions. Section 3 provides the psycholinguistic background to begin to provide answers to these questions, which is attempted in section 4.

Arguably, a theory that accounts for language competence and language processing is more complete and more useful than a theory of competence alone. Language comprehension and language production are *one* cognitive activity that humans engage in with language, and although not necessarily of interest to all linguists, comprehension and production are of interest to many. In this paper, I also aim to demonstrate that language processing can help resolve open research questions even when the primary interest is in grammatical competence and its development. Processing considerations must be taken into account whenever data obtained from language processing tasks – comprehension and/or production – are used to understand linguistic competence. I address some of the educational considerations with respect to the training linguistics students receive in the remainder of this introduction.

The claim that linguistics should deal with both competence and processing is, of course, not unique. In practice, the broadening of the scientific domain of linguistics is well on its way, at least in some countries, as evidenced by the number of linguistics programs that offer psycholinguistics specializations. In the US, many linguistics departments are training linguists to work as psycholinguists. To get a quick sense of these trends, we can eyeball the data provided by the Linguistics Society of America (LSA) Annual Reports concerning training and specialization areas offered by Linguistics Departments with doctoral programs. Among the Linguistics Departments with doctoral programs, the number of departments offering a psycholinguistics concentration area was 32 in 2013 and 37 in 2018. These estimates are to be compared with those for the more widespread classic concentration areas in syntax, semantics, and phonology. Estimates for syntax are: 49 in 2013 and 52 in 2018; phonology: 45 in 2013 and 45 in 2018; semantics: 42 in 2013 and 46 in 2018. A useful comparison is also with computational linguistics, another non-classic concentration area with a high appeal for its broader occupational outlooks: 20 programs in 2013 vs. 28 in 2018 (Linguistic Society of America, 2014, 2019). Specializing in processing (psycholinguistics) isn't any different than specializing in syntax, semantics, or phonology.

Everyone will agree that good science relies on good theories and solid methods. Despite lingering debates about linguistics as an empirical science (e.g., Gibson & Federenko, 2010, 2013), theoretical linguistics employs empirical methods just as much as psycholinguistics does, and conversely, psycholinguistics produces theories just as much as theoretical linguistics does. Linguists conduct experiments and collect behavioral measures obtained from live human participants (unlike, say, historical

linguists), typically in the form of speaker judgments. They rely on a linking hypothesis made explicit by linguistic theory that speakers' competence (a property of the underlying cognitive system) can be accessed this way. The cognitive construct (linguistic competence) will be reflected in the behavior (acceptability judgment) with a certain signal to noise ratio. This is just like any other area of cognition, as in, for example, the linking hypothesis that uses gaze-duration to reflect underlying attentive processes.

Decades of linguistic research have proven that experiments with acceptability judgments as their primary dependent variable yield good signal to noise ratios in many domains, especially in the domain of syntax, where most of the research using this method has been done. Recent large-scale studies have confirmed that the empirical base with respect to judgment data is solid and sound. Effects are reliable, replicable, and typically large (Sprouse, 2011; Sprouse & Almeida, 2012; 2017; Sprouse, Schütze & Almeida, 2013; see also Phillips, 2009; Phillips & Lasnik, 2003). Acceptability judgments are alive and well – there is every reason to be happy – especially at a time when other areas of science, ranging from the life sciences to medicine and the social sciences are challenged by replication failure (Marantz, 2019).

However, my claim is that a full account of how humans represent, comprehend, and produce language requires an account of both competence *and* performance. So if the linguist's interest is in processing, then, in addition to representational questions, questions about time-course, cognitive architecture, processing style, interaction with other cognitive domains such as long and short-term memory, etc. are no longer part of the "noise" part of the equation, they become directly part of the object of inquiry, and the methods used to study processing also become part of the tools of the trade.

In this paper, I present the argument that knowledge about language processing in adults and knowledge about the development of the language processing systems in young children, apart from being interesting topics in their own right, are relevant to competence theories, and especially to language acquisition theory and theories of language impairments. Take the case of language production data: what children or individuals with language impairments say (or do not say) may be the effect of missing/developing competence (immature/impaired grammars) but also of immature/impaired processing systems. Section 4.2 will illustrate this point using the acquisition of the passive to argue for a processing account of delayed passive acquisition, against a grammatical competence account. This one case will also bear on an important ongoing more general debate

in language acquisition: the early abstraction versus item-specificity account of young children's early sentence representations.

To conclude this section, acceptability is neither surpassed nor under attack, quite to the contrary. The success of acceptability should, however, not come at the expense of other measures such as reaction times, eye-gaze, response probabilities and error patterns, pausing and dysfluencies, hemodynamic or electrophysiological responses. Depending on the question and the linking hypothesis – how the measure reflects underlying cognitive activity, these measures are also part of the linguist's tool kit.

In order to carry out good experiments (robust, generalizable, replicable), linguistics students must be trained as cognitive scientists and be held to the same standards as in any domain of cognitive science/neuroscience. Research methods and data analysis courses are just as important as classic core areas (syntax, phonology, semantics, and pragmatics), and Linguistics Programs must include them in their common core.

1.1 Linguistics, psycholinguistics and speech language pathology in the ICF framework

The International Classification of Functioning, Disability and Health (ICF-WHO, or ICF for short) is a classification system that belongs to World Health Organization (WHO) family of international classifications and is the current international standard to describe and measure health and disability. [1] The ICF is a complementary bio-psycho-social classification system to the more widely known medical classification system called the International Classification of Diseases (ICD) which allows users to classify diseases by diagnosis through the use of an alphanumeric coding system (e.g, F81.0, *specific reading disorder*; F81.81, *disorder of written expression*). The ICF offers a broader and conceptually different classification system to the ICD. Like the ICD, the ICF is grounded in the body with a list of body *functions* and *structures* (e.g., The structures and functions of the nervous system), but, unlike the ICD, the ICF also includes lists of domains of *activity* and domains of *participation*.

I suggest that ICF is highly relevant to linguistics, psycholinguistics and speech-language pathology, and, conversely, advances in these disciplines contribute to the ICF. The ICF is a classification system, not a

[1] It was officially endorsed by all 191 WHO Member States in the Fifty-fourth World Health Assembly in 2001 (World Health Assembly, resolution 54.21).

theory.[2] Although the ICF is still primarily used in clinical settings, I believe that knowledge of the ICF is also useful outside of clinical contexts.[3] Because the ICF is neutral with respect to theory, uses simple descriptive labels and does not resort to specialized terminology or excessive jargon, it allows researchers and practitioners working in different disciplines and with different goals (e.g., linguistics, psychology, neurolinguistics, neuropsychology, conversational analysis, speech-language pathology; language technology) to situate their theories and findings in the relevant ICF domains. Familiarity with and use of the ICF is a common framework that also facilitates transfer of knowledge from more basic science (linguistics, psycholinguistics) to clinical practice (speech-language pathology). The ICF can also be used as a general framework across the curriculum in speech-language pathology where students must receive training in both basic and applied aspects of language, communication, hearing and speech (e.g., Bencini, Galletta & Cascella, 2013).

In the ICF, the term *functioning* is a neutral term and it refers to all body functions, activities and participation. Similarly, the term *disability* is a neutral cover term that applies to impairments, activity limitations and participation restrictions. Central to the ICF is also the recognition of the role of environmental variables on human functions, activities and participation so the ICF also includes lists of *environments*. Because the ICF adopts a person-centered view, environments are broadly defined as consisting not just of the physical environment but also including the social, relational and cultural environments. Just like the ICD, the ICF uses an alphanumeric coding system with letter codes to identify the major domains for human functions (**b** stands for body functions; **s** stands for body structures), activities (**d**) and environments (**e**). In addition to the major codes the ICF uses Qualifiers following the codes: numbers 0-4 indicate level of impairment (0=none, 4=complete problem). Further qualifiers have different meanings: In the Activity/Participation domains there is a distinction between a person's ability to perform a skill (e.g., carry out a conversation) in his/her natural environment (performance

[2] One could argue that the ICF *does* reflect theoretical approaches, for example in making the distinction between language as a mental function and communication as an activity. I will not pursue this issue further in this paper, but it does have consequences with respect to how one approaches assessment and treatment of language and communication disorders.

[3] The ICF framework can be adopted outside of medical or clinical settings, such as education (see Bencini, Garofolo & Arenghi, 2018 for an application to the contexts and environments of Higher Education).

qualifier) vs. performing the skill in a standard setting, such as a clinic (capacity qualifier). The capacity qualifier in turn consists of 2 digits, indicating a person's capacity to carry out the activity without assistance and capacity with assistance (e.g., a speech-language therapist's use of picture prompts, cueing, etc).

There are several chapters in the ICF that are relevant to linguistics and psycholinguistics? Both linguistics and psycholinguistics are mentalist approaches in that they view language primarily as a mental function. The relevant ICF chapter is a "b" chapter, indicating that it belongs to body structures and functions. The body structures relevant to language are primarily in the central nervous system, whereas speech and hearing involves the peripheral nervous system and the anatomy and physiology of of speech/sign. The body functions related to language in the ICF are listed in their own macro-chapter called *Mental Functions of Language*, which is itself embedded under *Special Mental Functions*. The *Mental functions of Language* chapter has its unique identifying alphanumeric code (b167). It, too, is a macro-chapter containing additional chapters: b1670 indicates all of the chapters having to do with language comprehension (the ICF uses the term "reception"). These include separate chapters for spoken, written, and sign. Everything having to do with language production ("expression" in the ICF) is coded b167, and likewise includes chapter for spoken, written and sign.

In summary: within the ICF, all of the chapters in b167 are in the domain of linguistics and psycholinguistics. If the interest is also in communication (for example within more functionally oriented linguistic approaches including conversational analysis or discourse-pragmatic approaches; but also psycholinguist approaches to dialogue) all of the relevant chapters are included in a separate domain, called activities. Communication has its own large macro-chapter: d3. The alphanumeric code indicates that communication is an activity (not a core mental function) and this chapter encompasses everything that concerns communication, whether via language or other means.

To give a simple illustration of how the coding system works, consider the case of a person with language impairment – who, as the result of their language impairment, also has difficulties carrying out a conversation. The ICD does not have diagnostic codes for seemingly mundane things like "impaired conversation". The ICF does. The relevant ICF macro-chapter is d3 (Communication), specifically 3501 *sustaining a conversation* which is defined as "Continuing and shaping a dialogue or interchange by taking turns in vocalizing, speaking or signing, by adding ideas, introducing a new topic or retrieving a topic that has been previously mentioned" (ICF

2001). She/he would therefore receive a 3 (indicating severe impairment) on the corresponding activity, followed by a 2 code for capacity qualifier without assistance (indicating moderate impairment) in a standardized environment such as a speech-language therapy clinic and a 1 score for capacity with assistance. To summarize, the corresponding ICF code would be: d350.3.2.1. The code reads: severe impairment in conducting a conversation in a natural environment, moderate impairment in a standardized setting without assistance, mild impairment with assistance (example adapted from Bencini, Galletta & Cascella, 2013).

2. Open questions at the interface between linguistics and psycholinguistics

Research in linguistics and psycholinguistics has often been conducted independently, leaving several outstanding questions unanswered (e.g., Bencini, 2013, 2017; Marantz, 2005; Lewis & Phillips, 2015; Phillips & Eherenhofer, 2015). These questions are listed in (1) – (3):

1) *What is the nature of the relationship between the grammar and the processing systems? Specifically, are the grammar and the processing systems part of one or more cognitive systems?*

This question is foundational and has consequences both for studies of grammar and language processing, but very little research has addressed it directly. Lewis & Phillips (2015) discuss two alternatives: "One-System Hypothesis" vs. "Two-System-Hypothesis". They define a cognitive system as "a collection of cognitive mechanisms with a distinct purpose, operating over representations of a distinct kind" (p. 28). If the representations employed by the processing system(s) are qualitatively distinct from the representations employed by the grammar, the relevance of grammatical theories to understanding how humans comprehend and produce language would be seriously limited. In section 4.1, I argue that language production errors provide strong evidence that the units in production are always linguistic in nature and obey linguistic constraints at some level, even when what is produced is an error. Lewis & Phillips make a similar point for errors in comprehension, discussing the case of grammatical illusions. Another facet of the Two Systems Hypothesis concerns the relationship between language comprehension and language production. This important question is addressed separately as question 3.

2) *Is there representational and processing continuity between child and adult grammar? To what extent are the grammatical constraints found in adult grammars also operative in child grammars? Do the performance systems operate similarly in children and adults?*

These questions are crucial to language acquisition theory. They are also critical to assessment of language development and language disorders (see, for example, Charest & Johnston, 2011). When child language deviates from adult language, it is important to be able to understand to what extent these deviations are due to non-adult or impaired grammars (a competence problem) or a processing effect. In section 4.2, I use the acquisition of the passive construction in the context of a broader debate in language acquisition, and make the case for representational and processing continuity.

3) *What is the relationship between the cognitive systems of language comprehension and language production? Are they one cognitive system or two?*

The language processing systems may operate on distinct modality specific representations as suggested by prominent views in neuropsychology. Caramazza (1997) has argued against the existence of abstract a-modal linguistic representations shared between comprehension and production (technically he has argued against *lemmas* in language production models, see section 3.3). In section 4.3, I use data from cross-modality structural priming to suggest that comprehension and production operate on shared abstract linguistic representations, contra a modality specific view that suggests that language comprehension and language production are two separate cognitive systems.

A central goal in adult psycholinguistics is to understand how humans comprehend and produce language in real-time. Psycholinguistics, by definition, deals with both competence and performance. A full account of comprehension and production, in fact, requires specifying both the nature and format of the representations, the operations involved, the time-course and the order in which different operations take place. Questions concern whether processing is *serial* – i.e., each module must finish its computations before passing them on to another module; whether it is *cascading* – i.e., downstream modules may begin processing information before upstream modules have completed their operations. Finally, an important question is whether the model is *interactive* – i.e., downstream modules may influence computations upstream (see Bencini, 2013; Bock,

1995; Bock & Levelt, 1994; Bock & Ferreira, 2014; Garrett, 1975, 1980; Dell & Reich, 1981; Dell, Martin & Schwartz, 2007; Ferreira & Svlec, 2007; Levelt, 1989; Levelt, Roelofs & Meyer, 1999 for reviews and evidence for and against the different versions of the overall modular consensus model for language production).

A generally positive property of language processing methods is that they typically measure participants' unconscious and automatic responses to conceptual, visual and linguistic stimuli. The last 10-15 years have seen an increasing interest in language processing research in diverse populations, and especially in children. Many of the questions and methods in child language processing are imported from adult psycholinguistics and adapted to different populations of learners (child learners, adult learners, learners with impairments). These methods offer a useful complement to off-line acceptability tasks (Marinis, 2010). Both online and offline implicit methods can be adapted to be used with a range of participants, including very young children and people with language and or cognitive impairments. In section 3, I review psycholinguistic theories and methods and studies with children and adults that can shed light on different aspects of questions 1-3.

3. Language processing in adults and children

3.1 Language processing is *both* language comprehension and language production, not just comprehension!

To the extent that linguistics has considered processing data to be relevant to theory, it has turned more towards comprehension than production data (Bencini, 2013; Bock, 1995). In part this has to do with the substantial methodological lag between comprehension research and production research, but perhaps it is also due to a persistent behaviorist view that the mapping from thought to language is shallow. Bock (1996) calls this the "mind in the mouth" assumption. The "mind in the mouth" view of language production contrasts with the information processing view developed within psycholinguistics (e.g., Bock, 1982; Levelt, 1989), which instead views talking and signing as prodigious acts of linguistic creativity. As we will see in more detail in section 3.3, language production involves a highly complex multi-staged cognitive system with a modular architecture, representations that are linguistic in nature and operations that consist of the selection, retrieval and assembly of linguistic units at different representational levels, in the right order (linearization),

under time pressure (Bencini, 2013, 2017; Bock & Levelt, 1994; Bock & Ferreira, 2014; Ferreira & Svlec, 2007; Levelt, 1989).

Failing to consider that language production (producing language in real time) *is* an instance of language processing more generally – just like comprehension – is especially problematic when it comes to language acquisition theories and in any clinical domain, whether with children or adults. We will return to this in sections 3.3.1 and 4.2. To highlight this important point, in language acquisition research many claims about children's grammatical competence are made directly on the basis of what children produce, without sufficient consideration that what children say is partly a reflection of their grammatical system, but also the output of their language processing system(s) (Bencini & Valian, 2008; see also McKee, McDaniel & Garrett, 2018 for an overview and appraisal of all of the research examining the development of the language production system).

3.2 Language comprehension processes in adults and children

Language comprehension research at the sentence level examines the means by which speakers compute the meaning of a sentence as a whole from the words in the sentence Although it includes performing a syntactic analysis (parsing), it is not limited to parsing, as the output of sentence comprehension is an interpretation (Pickering, 1999). Psycholinguistic models generally accept that sentence comprehension involves representational modularity over phonological, syntactic and semantic representations, but the extent to which the modules are subject to serial versus interactive processing in dynamically constraining the interpretation of the input as sentences unfold is a matter of debate.

There are essentially two contrasting theoretical views. According to more structural accounts, the initial processing of a sentence is performed relying exclusively on syntactic information; other types of information (e.g., lexical and pragmatic information) come into play at a later stage (following Frazier & Fodor, 1978). In contrast, constraint-based theories (e.g., MacDonald, Pearlmutter & Seidenberg, 1994; McRae, Spivey-Knowlton & Tanenhaus, 1998; Trueswell, Tanenhaus & Garnsey, 1994) assume that the sentence processor uses all available constraints (lexical, structural, and discourse level constraints) immediately to build on-line interpretations of the input even if these interpretations require subsequent revision. Much of the visual world research in sentence processing in adults and children (reviewed in section 3.2.2) has been devoted to distinguishing between structural and constraint-based theories. Evidence reviewed in that section highlights both similarities and differences

between adult and child sentence processing, especially with respect to reanalysis and revision of initially preferred analyses that are later contradicted by additional input.

3.2.1 Off-line sentence comprehension: picture verification

One simple and widely used way to examine how adults and children interpret sentences is to give them a sentence verification task. Participants are presented with an auditory stimulus sentence to be matched to the correct target picture, in the presence of distractors that control for different factors. This task is still by far the most widely used task in many standardized and non-standardized clinical assessment tasks with children, adults and speakers with impairments, e.g., it appears in batteries such as: *Test of Receptive Grammar* (Bishop, 1982), *Clinical Evaluation of Language Fundamentals* (Wiig, Semel & Secord, 2013), *Psycholinguistic Assessment of Language Processing in Aphasia* (Kay, Coltheart & Lesser, 1992), to name a few. The task is also widely used in experimental tasks because it is easy to construct and it can be used with children between the ages of 30 and 36 months.

The availability of studies that use this task across different populations offers the advantage of being able to examine data developmentally, but there are also serious limitations to using this task if the goal is primarily to investigate early grammatical knowledge, as negative or null results are not informative. First, sentence picture verification tasks pose demands on working memory and are cognitively demanding. In addition to remembering the test sentence, participants must analyze two-four flanking pictures and decide which picture fits it better. Even adults find sentence verification tasks difficult, especially with non-canonical sentences such as passives (Brookshire & Nicholas, 1980; Slobin, 1966) where they are also less accurate in assigning correct semantic roles (Ferreira, 2003). Therefore, extreme caution should be taken when interpreting performance on this task (Bencini & Valian, 2008).

3.2.2 Online sentence comprehension: the visual world paradigm

The last several years have seen the introduction of the Visual World Paradigm to examine spoken language comprehension in adults and children (Altmann & Kamide, 1999, 2004, 2007; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995; Sedivy et al., 1999; Trueswell et al., 1999; Snedeker & Trueswell, 2004; see Cooper, 1974 for pioneering

research). Eye movement data provide a window into how listeners shift their visual attention in response to linguistic input. This technique is useful to examine what cues listeners use to constrain interpretations in real time processing, including sentences containing ambiguities.

In the seminal work by Tanenhaus et al. (1995), participants were presented with sentences containing prepositional attachment ambiguities, as in "Put the apple on the towel in the box", which, upon encountering the first PP "on the towel" is temporarily ambiguous between a goal argument interpretation of the PP "on the towel" and a modifier of the direct object interpretation. The visual world context provided participants with either one or two referents. In the one-referent condition, there was only one apple on a towel, an empty towel, a box, and a pencil. In the two-referent condition, there were two apples: one on a towel and one on a napkin. In the two referent condition, therefore, a modifier was needed to inform the listener which of the two apples to select. The eye-movement patterns showed an initial bias towards interpreting the incoming sentence with the PP as a goal, but adults also showed rapid use of contextual information to disambiguate sentence structures.

In a similar study comparing adults and five-year-old children, Trueswell et al. (1999) replicated the effects of context for adults, but not for the five-year-olds, who were equally likely to look at the empty towel in the one-referent and in the two-referent condition. These results suggest similarities in processing between children and adults in that both groups make parsing commitments immediately, but children have difficulties abandoning an initially preferred analysis once this analysis is contradicted by late-available contextual evidence. Abandoning an initially preferred analysis and revising it in favor of a dis-preferred analysis is assumed to require cognitive control and executive functions, which would explain the difficulties with revision exhibited by children and speakers with executive function deficits (e.g., Choi & Trueswell, 2010; Novick, Trueswell & Thompson-Schill, 2005).

Several additional processing phenomena have been investigated using the visual world paradigm, but a detailed review is beyond the scope of this paper. I do, however, believe that the visual world paradigm holds promise to investigate a range of representational and processing questions in different populations, including children and clinical populations.

For example, Hanne et al. (2011) combined a sentence-picture verification task using reversible passives to compare the off-line and online performance of German speakers with agrammatic aphasia. This study turned out to be very informative as to what goes on when speakers with aphasia select the correct versus the incorrect picture, and this

information is something that obviously an off-line measure (accuracy) cannot provide. When their participants with aphasia chose the correct picture, their eye-movement patterns were similar to those of healthy controls. The authors took the data to be more consistent with an impaired processing account for the comprehension deficit in agrammatic aphasia, rather than an account that posited a deficit in representations (e.g., Grodzinsky, 1986, 1995, 2000).

More basic research needs to be done before these results are translated to standardized assessment protocols, but studies such as the one by Hanne et al. add to our understanding of online comprehension processes in different populations. In addition to being useful to examine sentence processing (comprehension and production) operations in impaired speakers, eye-tracking also holds promise to track changes in sentence processing in response to treatment (Mack et al, 2016; Mack, Nerantzini & Thompson, 2017).

3.3 Language production processes in adults and children

Current psycholinguistic models of language production in adults adopt an overall theoretical framework that goes back to the initial proposals by Garrett (1975). The framework has undergone critiques, revisions, and refinements, but the overall layout of the system appears to stand the test of time (Bock & Levelt, 1994; Ferreira & Svlec, 2007; Levelt, 1989; Levelt, Roelofs & Meyer, 1999; Bencini, 2013; Pickering & Branigan, 1998; McKee et al., 2018). I will follow the terminology used in this literature, so the terms used are to be understood within the context of this framework. In addition to the more recent addition of eye-movement data to study production, language production research employs other types of behavioral paradigms and data. Some of the most common methods and data types are: error-elicitation and error types, lexical and structural priming, eye tracking.

Language production starts with a pre-linguistic representation called the *message* and proceeds through a multi-layered level called *formulation* consisting of representationally (and in some versions computationally) modular levels of *grammatical encoding* and *phonological encoding*. The output of the language production system is not speech, but a still fairly abstract phonological representation that serves as input to an internal phonetic plan (internal speech) which is then passed on to the *articulator* responsible for the sensory-motor plans for oral/manual articulation. Based on observations of constraints on speech error patterns (both naturally occurring and elicited), and a large body of lexical and structural priming

experiments, grammatical encoding is assumed to have a two-level architecture separating *functional* and *positional* processes (see Bock & Levelt, 1994; Levelt, 1989).

Functional processes are responsible for the selection of abstract linguistic representations called *lemmas* among candidate competing *lemmas* that may also receive activation from the message (and, in some variants, from additional levels, e.g., the interactive activation version proposed by Dell, 1986). Lemmas are abstract and underspecified for certain types of linguistic information (i.e., phonology, inflection). Positional processes retrieve the *word form* or *lexeme* linked to the lemma filling in the underspecified information.

A much debated issue within the general framework concerns processing style throughout the system, that is whether processing is *serial* and *discrete* (Levelt, 1989; Levelt et al., 1999), or whether it is *cascading*, allowing for lexemes to receive activation even prior to lemma selection. An additional question is whether the system is also *interactive*, allowing for lexemes not only to receive activation, but to also send activation "back up" to the lemma level, and therefore potentially influence the initial stage of lemma selection (Dell, 1986; Dell & Reich, 1981). Evidence for feedback comes from the observed higher than expected frequencies in error corpora of so called mixed-errors, that is errors that are both semantically and phonologically related to the target (such as saying "rat" when "cat" was intended) (Dell & Reich, 1981; Dell, Martin & Schwartz, 2007). The issue of information flow through the system is important and has consequences for how we interpret production data in adults, acquisition and disorders.

Although the architecture in terms of representation modularity is still preserved, interactivity a la Dell (1986) complicates the picture considerably, and makes pinpoint the locus of an effect (e.g., semantic, syntactic, phonological) harder than simply assuming that if, say, a child or speaker with aphasia produces "deviant" syntax, the locus of the effect is syntactic. If there is feedback throughout the system, it is possible for phonological representations (which are downstream in production models) to influence lemma selection, and potentially even function assignment, something I return to in section 3.3.1.1.

There is less research investigating the format of messages in young children and in adults. One proposal (Bencini, 2013, 2017) is that the representational format for messages is semantic event structures containing variables for individuals and events (e.g., X acts on Y; X causes Y to move to Z) and existing independent of more specific predicates (e.g., *give*, *move*, *send*). I take structural priming results in

adults and children (reviewed respectively in sections 3.3.1.1 and 4.2) to support this view.

3.3.1 Methods to examine language production processes

It is clear from the brief introduction above that language production is computationally complex. Current models assume that each component employs cognitive resources (e.g., Roelofs, 2008). If this is correct, the cognitive load from one component (e.g., lexical retrieval) may affect another component (e.g., syntactic formulation) resulting in tradeoffs between levels.

The possibility for tradeoffs between modules is especially important when studying children (whether typically developing or impaired). Phonetic complexity has been found to negatively correlate with the syntactic complexity of children's utterances. For example, Nelson & Bauer (1991) found that children with more mature oral-motor control (a clearly non-linguistic domain) also produce more linguistically complex language. Masterson (1997) found the same result with children with language impairment. It is clear, then, that one cannot therefore judge children's syntactic knowledge solely on the basis of what children say (or don't say) (McKee et al., 2018).

Some of the ways to ensure optimal conditions for syntax include focusing on form - not meaning, concentrated input focusing on one structure at a time, repetition (Deen et al., 2018; Valian & Aubry, 2005), and priming. In section 4.2, we will see how priming can been used to control for processing load and allow children to more accurately display their linguistic knowledge.

3.3.1.1 Structural priming in language production

Structural priming is the tendency to re-use previously processed sentence structures. This tendency can be observed in naturalistic situations including dialogue and corpora, but its primary use in psycholinguistics is as an experimental paradigm used to investigate linguistic representations activated during processing; to address modularity questions; to probe processing pathways. In the classic demonstration by Bock (1986), priming was demonstrated with active/passive and double object/prepositional dative constructions. Speakers were more likely to describe two-participant transitive events (e.g., a picture of dog chasing a man) with a passive if they previously heard and repeated an unrelated passive sentence with different nouns and verbs (e.g., *The 747 was alerted*

by the airport control tower). Structural priming has been extremely successful in uncovering how language production works in adults and more recently in children (for reviews see Branigan, 2007; Branigan & Pickering, 2017; Bock & Ferreira, 2006; Pickering & Ferreira, 2008). A variant of structural priming, cross-modal structural priming (from comprehension to production) also sheds light on the relationship between the processing systems. We will return to this in section 4.3.

The reason why priming is a useful experimental technique is that it affords inferences about the dimensions to which the language production system is sensitive to, both in adults and in children. By systematically manipulating the overlap between priming sentence stimulus and target sentence priming has allowed researchers in adult psycholinguistics to uncover the distinct stages involved in producing sentences (e.g., Bock, 1986, 1989; Bock & Loebell, 1990; Pickering & Branigan, 1998). The original structural priming studies by Bock and colleagues (e.g., Bock, 1986, 1989; Bock & Loebell, 1990) found lexically independent priming. Bock & Loebell (1990) found priming in the absence of thematic role overlap between prime and target and in the absence of function word overlap.

Pickering & Branigan (1998) and Cleland & Pickering (2003) found enhanced priming when the verb was shared between prime and the target – this is now referred to as the *lexical boost* effect. They also found that priming was unaffected by whether tense, aspect, or number of the verb stayed the same or differed between prime and target. Verb independent priming in adults is taken to be a signature of abstract sentence representations at work in language production.

Bock & Loebell's widely cited results have recently been questioned by Ziegler, Bencini, Goldberg & Snedecker (2019), who replicated and extended their original (experiment 2) finding that in English, priming of passives does not depend on semantic role overlap between prime and target. However, our new study did find clear evidence of the influence of the *by* phrase. How can we reconcile this novel finding with other findings that have suggested no role for function words in priming? Specifically, Bock (1989) argued against a contribution of prepositions because she found that benefactive datives containing the preposition *for* in the prime sentence were as good as prepositional datives containing the preposition *to* in eliciting *to* dative descriptions.

First, this finding highlights the importance of examining the contribution of each factor orthogonally and independently across constructions – one cannot (unfortunately) assume that the priming results that examined the contribution of the preposition (Bock, 1989) for datives

will automatically extend to active/passives. Second, one possible account for this novel (and, to many unexpected) result is to account for it within a modular language production model that has a cascading activation and interactivity (following Dell, 1986). In this account, the prepositional phrase "by NP" would feed information forward (cascading) before function assignment is complete, activating the phonological encoding level (/baɪ/) which in turn would influence function assignment via feedback from the phonological encoding level to the level of grammatical encoding.

There already is substantial evidence for feedback from phonological encoding to lemma selection from speech error data (both naturalistic errors and errors produced in error elicitation paradigms) (e.g., Dell & Reich, 1981; Dell, Martin & Schwartz, 2007; Rapp & Goldrick, 2000; see Bencini, 2017 for a review). As suggested above, this would be a case of feedback from phonological encoding to function assignment obtained *under structural priming conditions*. This point is important to bear in mind with respect to the generality of the effect. We must always keep in mind what speakers are doing in a structural priming experiment in language production: they are always describing scene sketches (Henderson & Ferreira, 2004) depicting transitive events that, as established prior to priming, are already compatible with the semantics and pragmatics of the passive. Target pictures to be described are typically scenes with salient animate patients/themes and either inanimate or animate agents (e.g., alarm clock awakening a boy, bee stinging a man, dog chasing a mailman, horse kicking a cow, etc.). Under the feedback from the phonological encoding level account I propose here, the Ziegler et al. results are accounted for in terms of a "late", i.e., surface effect where phonological encoding (via feedback) impacts on function assignment during grammatical encoding.

In section 4.2, I show how results from priming experiments in very young children can contribute to making progress in current debates on the acquisition of certain grammatical structures, such as passives, and more generally on current debates in language acquisition.

3.3.1.2 Online methods: Eye tracking in language production

One promising way to investigate the mapping from message generation to online production is to record eye movements to scenes and events during controlled language production tasks and to examine the temporal links between the two (Griffin & Bock, 2000; Bock, Irwin & Davidson, 2004, see Konopka and Brown-Schmidt 2014). Griffin & Bock (2000) pioneered

the use of eye tracking in production with adults. No equivalently detailed studies employing eye tracking in language production, to my knowledge, exist with children, although some studies have compared looking patterns in children and adults to ensure that the source of the differences between child and adult language production did not reside in the initial message generation phase (e.g., Bunger, Papafragou, & Trueswell, 2013).

Griffin & Bock showed speakers the typical scenes used in production research: line drawings depicting transitive actions between participants. Based on the examination of eye-gaze patterns across different tasks, Griffin & Bock found evidence for two distinct phases: an initial apprehension phase lasting about 300 milliseconds, during which speakers comprehend the event (Message generation), and a following formulation phase during which they linguistically encode and overtly produce the utterance.

This eye-movement in production task is particularly revealing about the time-course of formulation and reveals aspects of language production in adults that can shed light on child language production. In Griffin & Bock's study, the order of speakers' looking patterns to the referents in the pictures reflected their order of mention during the overt speaking phase. In other words, looking and speaking were time-locked. This important finding suggests that it is useful to trace when speakers apprehend visual inputs for message generation and to relate this information to the content, form and timing of their unfolding utterances.

Additional eye tracking in production research with adults has revealed the extent of the links between eye gaze and spoken output. Speakers have been found to gaze at each referent immediately before mentioning it (Griffin, 2001) even when they could easily retrieve the information from working memory (such as when they mention the referent again within a short utterance) (Meyer, van der Meulen & Brooks, 2004). Different accounts have been proposed for the tight temporal link between eye movements and planning of speech (see Griffin, 2004). But, by and large, point of gaze is interpreted as a behavioral correlate of the current focus of a speaker's attention. Because lexical retrieval is a cognitively complex operation and requires processing capacity, being able to attend to a referent while speaking may be one way the cognitive system has to facilitate lexical retrieval during sentence generation (see Griffin, 2004 for further discussion).

4. In search of answers to the open questions for linguistics and psycholinguistics in adults and children

4.1 Constraints on misalignments between grammar and processing: Evidence for a One-Cognitive System View from errors in language production

Early evidence for the Two-stage model of language production came from the detailed analysis of speech error data. For example, Garrett (1980) noted that lexical level errors (substitutions, blends) fell into two categories: those that were semantically related to the target and those that were phonologically related. Errors occur in all languages (including sign languages).

Language production errors (more commonly known as speech errors, or slips of tongue) are by definition instances of misalignment between messages (the speaker's intended meaning) and formulation. Language production errors are not to be confused with motor-articulatory errors (as in motor-speech disorders) as they still reflect pre-articulatory stages. Depending on the characteristics of the error and the observed constraints on errors, psycholinguistic models can be used to pin-point the locus of the error, in monolingual adults (Bock & Levelt, 1994; Bencini, 2017), children (McKee et al., 2018), and speakers with language impairments (e.g., Dell et al., 1997).

The important observation with respect to the relationship between the grammar and the processing systems is that even errors (which are paradigm cases of misalignment between grammar and processing) provide evidence for a single cognitive system. The fact that errors are, by their nature, neither strategic, nor metalinguistic, makes them interesting sources of data to consider.

In native speaking adults, there is no error that does not involve some level of linguistic analysis (feature, segment, syllable, morpheme, phrase) or does not obey constraints at some level (Bock & Levelt, 1994). Because errors involve linguistic units, which may be exchanged, moved around, or stranded during spoken production, I have argued elsewhere that performance errors are not informative only for processing models; they are also informative for competence models. They provide striking converging evidence that the units of phonology, morphology and syntax are both representational and processing units (for more extensive discussion of this point and for the relevance of error data see Bencini, 2017).

McKee et al. (2018) provide an illuminating comparative review of existing child error data against adult error data (see also work by Jaeger, 1992, 2005; Stemberger, 1989; i.a.) and observe that, by and large, children produce, qualitatively, the same kinds of performance error that adults do. Importantly, the same constraints on speech errors observed in adults are also observable in the speech of young children.

Lewis & Phillips (2015) argue for a One-System-View by examining cases of misalignment between grammar and processing in language comprehension in children and adults. Misalignments in production (production errors) show no evidence for distinct cognitive systems operating on representations of a distinct kind. They provide converging evidence for a One-System View.

4.2 Structural priming in young children and the early production of passives: Evidence for representational and processing continuity in children and adults

Children (and adults) find passive sentences harder than actives. We have known this from the earliest days of language acquisition research (e.g., Slobin, 1966; Bever, 1970). What we don't really know is why passives are hard. Several competence-based explanations have been proposed to account for children's difficulties with passives over the years (Borer & Wexler, 1987, 1992; Fox & Grodzinsky, 1998; Snyder & Hyams, 2015; Wexler, 2004; see Deen, 2011 for a review).

Apart from being an important research question in language acquisition per se, this section focuses on the contribution that studies on the acquisition of passives by very young children (3-year-olds) have made to a much larger current debate in language acquisition. The big question, put simply, is: how abstract are children's early syntactic representations?

Structural priming has played an important role in this debate as evidence of abstract priming in young children provides evidence for abstract representations of the structure exhibiting priming.

The first published structural priming study with young children was the study by Savage, Lieven, Theakston & Tomasello (2003). The explicit aim of the study was to assess the abstractness of early sentence representations via the primed production of actives and passives under priming conditions that manipulated lexical (verb) overlap between prime and target. Children aged 3, 4 and 6 watched simple action-event cartoons on a computer screen. The experimenter showed the child a priming scene, for example a stick hitting a door, and described the scene four times. The

child was then asked to repeat the prime. In the target cartoon, a novel action performed by two new inanimate objects appeared on the screen, for example a 'digger breaking a brick,' and the child was asked to describe it. All of the cartoons involved inanimate objects performing an action on other inanimate objects. In the low lexical overlap condition, the experimenter described the priming scene with full noun phrases, for example *The stick is hitting the door*. In the high overlap condition, the experimenter used pronouns instead of full nouns, for example *It is hitting it*. In the high overlap condition, it was therefore possible for the child to re-use the pronouns to describe the new event: *It is breaking it*. They found that six-year-olds showed priming when the prime and the target did not overlap lexically, but that three- and even four-year-olds only exhibited priming in the high overlap condition. They concluded that before the age of six, children's representations of transitive sentences are not abstract, but that lexical items such as pronouns and grammatical morphemes are an integral part of their sentence representations. In the procedures used by Savage et al., the objects in the scenes were novel and unknown to the child before their presentation on the screen. Producing a noun phrase for a novel noun requires among other things lexical lookup and retrieval. It is therefore possible that the failure of this study to find structural priming before age six was the result of a floor effect, and in part due to the materials and procedures employed. These extra processing demands, along with an already lower probability of passive descriptions, may have resulted in the younger children simply not producing passives.

The Savage et al. (2003) results contrast sharply with those of Bencini & Valian (2008), despite having similar design and linguistic materials (inanimate agents and patients in both primes and targets). We also tested a very young group of three-year-olds, our participants were 2;11-3;6, with a mean age of 3;2. We reasoned that lexical access and retrieval would be more taxing in young children at the expense of sentence generation. We therefore introduced modifications to the adult priming paradigm, specifically "lexical warm-up" phases immediately before short priming blocks, consisting of two instances of a prime-target, before another lexical warm-up phase for the next block of two prime-targets. Crucially, we also used a warm-up phase for the verbs, not just the nouns.

Because the study was aimed at addressing the broader debate in language acquisition, we contrasted the predictions of Lexical Specificity (Childers & Tomasello, 2001; Lieven, Pine & Baldwin, 1997; Olguin & Tomasello, 1993; Tomasello, 1992, 2000a, 2000b) and Early Abstraction (Gertner, Fisher & Eisengart, 2006). Several authors had noted that discrepancies between comprehension and production data reflected a

"Paradox" in language acquisition whereby children possibly relied on abstract representations in comprehension but not in production (see Fisher et al., 2010 for a nice review of the comprehension data).

Under a Two-System or (Multiple-System) view, however, it is entirely possible that the processing systems develop independently and that representations are abstract in one system, but immature in the other. To the extent that comprehension and production data show similar representations in language development, this is an argument both for continuity and for a One-System View.

Bencini & Valian's results showed reliable priming of full passives in English speaking 2;11-3;6 year olds (the youngest group to date), under semantic and discourse conditions chosen to disfavour passives semantically (all stimuli had inanimate agents and inanimate patients) and in conditions that did provide discourse support for the passive. Many priming studies confirm these priming results for *English* (e.g., Branigan, McLean & Jones, 2005; Huttenlocher, Vasilyeva & Shimpi, 2004; Shimpi et al., 2007; Messenger, Branigan & Mclean, 2011; Messenger et al., 2012; Rowland et al, 2012); see Manetti (2013) for priming of passives in *Italian*. Several other studies find production of passives in pre-schoolers under discourse conditions that facilitate patient topic sentences such as passives (e.g., the experimenter asks the child to tell him/her about $X_{patient}$) (see Kline and Demuth, 2010; Manetti, 2013; Manetti & Belletti, 2015; Pinker, Lebeaux & Frost, 1987; Volpato, Verin & Cardinaletti, 2014, 2016; i.a.).

The replication of abstract priming in child language production across many labs and with different languages gives confidence to the validity and robustness of the findings.

Taken together, the syntactic priming results with full passives in conditions that minimized processing operations specific to production (e.g., lexical access) but extraneous to the question (sentence generation) lead us to conclude that the documented paucity of full passives before age 5 in English and other languages are processing difficulties, not grammatical difficulties. On this account, there is no maturational component to the grammatical representations and operations required by passives. Children have representations of the passive structure that are qualitatively identical to adults (e.g., Bencini & Valian, 2008; Demuth, Moloi & Machobane, 2010; Deen et al., 2018; Messenger et al., 2011 i.a.).

This case serves to illustrate why convergence between theories of representation and theories of processing is important even if one's primary interest is in competence. Interestingly, the production data go against two prominent accounts that reside at polar opposite end of the

continuum with respect to the nativism vs. empiricism debate in acquisition: nativist maturational accounts on the one hand (following Borer & Wexler, 1987) and empiricist constructivist accounts on the other (e.g., Tomasello, 2000a, 2003).

The point I wish to make is that irrespective of theoretical position with respect to nativism vs. constructivism debate, production data are the product of a performance system. I agree with McKee et al. (2018) that any work in language production in children must be seen within the context of models/theories of language production, even if the ultimate goal is to arrive at children's competence. Understanding how language production works in children helps researchers design better studies (i.e., that control for production specific factors) and make it easier to reveal children's knowledge. This extends to clinical populations and children growing up with more than one language.

4.3 Cross-modality structural priming and the relationship between language comprehension and language production: Evidence for One shared Cognitive System

I finally turn to the third question, concerning the relationship between language comprehension and language production, specifically if these two cognitive systems operate over representations of a distinct kind. Because comprehension and production have for the most part been studied independently, this question has rarely been investigated directly.

Language comprehension and language production appear distinct enough that learners both of their first and of their second or subsequent languages manifest discrepancies in their abilities to understand and to produce language, with comprehension skills usually surpassing production ones (Clark & Hecht, 1983). Dissociations between comprehension and production abilities in both intact and language-impaired individuals have been argued to provide evidence for distinct representational systems for comprehension and production (e.g., Caramazza, 1997).

One important study that bears on the relationship between the representations in comprehension and production and argues against a Two-Cognitive Systems view uses a cross modality task from comprehension to production. In the study by Bock, Dell, Chang & Onishi (2007), participants were primed with spoken sentences in different structures (active/passive; double object/prepositional dative) without repeating them. Because priming involves re-accessing and re-using previous representations/processes, if the processing systems operated

over distinct (modality specific) representations, processing a sentence through the comprehension system alone should not activate and engage the same representations/processes as producing the primes (i.e., repeating). Under a Two-Cognitive-Systems View (e.g., Caramazza 1997) comprehension-to-production priming should not pattern like production-to-production priming. Under a One-Cognitive-System View, similar priming effects in terms of magnitude and duration are expected across modality. Remarkably on a Two-Systems View, the results showed similar cross-modal priming, both in terms of magnitude and temporal duration, to previous within-modality priming results (Bock & Griffin, 2000).

I take the positive findings from cross-modal priming studies to argue strongly for the existence of modality general abstract representations between comprehension and production. Similar cross-modal priming results can also be found for spoken to written priming (Pickering & Branigan, 1999), arguing for shared representations irrespective of output modality (speaking/writing).

The mechanism that ties representations in one modality to other modalities is not yet understood. One possibility is that the links are tied to the mechanisms of language acquisition (Chang, 2002; Chang, Dell & Bock, 2006; Chang et al., 2000). If children are biased to represent language abstractly from the outset, this would support generalization from listening to speaking. Cross-modal priming has been observed in young children: Shimpi, Gámez, Huttenlocher & Vasilyeva (2007) found cross-modal abstract priming, in four-year-olds (but not in younger children). More studies should investigate cross-modality in learning and in different populations of learners.

5. Conclusion

The main goal of this paper was to advocate for the benefits of convergent theories of language representation and language processing in children and adults. Over the course of the article, I have pulled together findings from different research areas that have often developed independently, such as language acquisition, language comprehension, and language production. We need more "convergent" research that compares competence and processing in adults, child learners, adult learners, bilinguals and speakers with impairments. But the evidence that the systems for competence and processing are one cognitive system is good news for linguistics.

In this paper, I have also claimed territory for linguistics outside of the classic domain of language competence. Many linguists work on language

processing already, as this is also reflected in increasing numbers of linguistics programs offering psycholinguistics in addition to the classic "core" areas: syntax, semantics, phonology. For the purposes of "talking" to other disciplines, especially – but not exclusively – those interested in the clinical applications of psycho-neuro-linguistics, I find it helpful to adopt the descriptive coding system of the ICF introduced in section 2. In "ICF speak", this means that all of the Chapters under b167, "Mental functions of Language" are in the scientific scope of the field of linguistics. In the first section of the paper, I listed some of the implications of this broadening scope of practice for the training of future linguists highlighting the importance of research methods in addition to foundation courses in core linguistic areas.

I have also tried to do justice to language production, partly because it is the less studied language processing system, but also because of the importance of keeping this in mind when production data is used to probe mental grammar. I have insisted on the importance of looking at language production tasks as processing tasks both from the perspective of experimental design (making sure we are not underestimating cognitive load) and in the interpretation of language production data. With respect to child language acquisition, I suggest that findings originally imported from the adult psycholinguistics literature on sentence production explain phenomena that have traditionally been attributed to stages in children's grammatical development, such as the slow development of productive use of the passive. The findings are twofold. First, in conditions that control for processing factors in production (specifically lemma access), children produce syntactic forms (such as passives) at earlier stages than predicted both on constructivist accounts and on maturational accounts. Second, children's processing systems show the same effects as adults. Studies that have directly attributed children's performance effects to lack of mature grammatical knowledge would benefit from incorporating the perspective from language processing..

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