Systemic functional grammar as a tool for experimental stimulus design: new appliable horizons in psycholinguistics and neurolinguistics

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ABSTRACT

Since their onset more than 50 years ago, both psycholinguistics and neurolinguistics have provided crucial breakthroughs for understanding the cognitive bases of language. Despite their major contributions, however, both fields have been undermined by a tradeoff between ecological validity (i.e., the degree to which tasks reflect the conditions of everyday communication) and experimental control (the manipulation of fine-grained variables, which is typically achieved by matching lists of decontextualized words and sentences). Specifically, most extant research sacrifices the former requisite in pursuit of the latter, or vice versa, but both are rarely met in combination. To overcome this problem, we have relied on Systemic Functional Linguistics (SFL) and designed a protocol for constructing carefully matched but fully naturalistic narratives usable in experimental settings. First, we describe the limitations of mainstream language experiments and their poor ecological validity. Second, we introduce an SFL-based protocol that allows constructing naturalistic stories that differ in one critical target variable while guaranteeing statistical comparability in multiple other factors. Third, we illustrate how the protocol has been successfully implemented in two groundbreaking studies exploring the links between biological motor systems and lexico-semantic processing. Finally, we discuss the potential gains springing from future collaborations between SFL and experimental language research.

1. Introduction

Since their onset more than 50 years ago, both psycholinguistics and neurolinguistics have provided crucial breakthroughs for understanding the cognitive bases of language. In particular, both disciplines have proven critical for characterizing the internal mechanisms supporting language comprehension, production, acquisition, and loss (Hickok and Small, 2015; Traxler,

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2011); the causes of language disorders (Birba et al., 2017; Cervetto et al., 2018; Franceschini et al., 2013; García and Ibáñez, 2018; Marini et al., 2011; Pulvermüller, 2002); the neural correlates of syntactic processing (Zaccarella and Friederici, 2017); the psychobiological foundations of reading skills (Carreiras et al., 2014; Dehaene, 2009; McCandliss et al., 2003); and the organization of different language systems in bilingual individuals (García et al., 2014; Timmer et al., 2017), to name but a few areas of research. Though hugely informative, however, most of this evidence faces a major limitation: it comes from highly artificial experimental tasks which consist of randomized lists of decontextualized words or sentences, thus proving blind to the richness of the coherent and cohesive texts that people constantly face in their daily lives. As a consequence, knowledge about the neurocognitive mechanisms acting on discourse-level processing is still inadequate. In this sense, a pressing challenge for neurocognitive language research consists in designing carefully controlled but still ecologically valid experimental materials that do not sacrifice naturalness to statistical control or vice versa. In the present paper we argue that this problem can be effectively circumvented and, more particularly, that specific solutions can be (and have been) afforded by a specific linguistic theory: Systemic Functional Linguistics (SFL).

Conceiving of language as a systemic resource to construe meaning in everyday interactions (Halliday, 1978; Halliday and Matthiessen, 2004), SFL sets forth a stratificational architecture leading from context to semantics to lexicogrammar to phonology through ever more delicate choices. Contextual information is proposed to encompass three key variables, namely: field (the subject matter and overall setting governing the communicative event), tenor (the relationship among physical or implied interlocutors), and mode (how a text is constructed in a particular situation depending on the channel used to transmit information). These parameters are linguistically manifested in three strands of meaning, termed ideational (concerned with the construal of events and entities in the world), interpersonal (concerned with the representations of relationships among people in a situation), and textual (concerned with the role of the medium of communication and the text's rhetorical function). Chosen configurations in these semantic dimensions are realized by particular lexico-grammatical patterns, themselves selected from a wide range of options. Those wordings are then realized as phonological sequences, which are in turn realized by phonetic items. With this overall framework and numerous specifications therefrom, SFL is capable of accounting for a myriad of linguistic, communicative, and discourse-level phenomena (Hasan, 2019; Martin and Zappavigna, 2019a, 2019b), beyond the constraints of formal theories focused on sentential analysis.

The theory has been fruitfully permeable to interdisciplinary dialogue with other research fields, including sociology (Hasan, 2004; Maton and Doran, 2017), education (Christie, 2016; Christie and Martin, 2009), informatics (O'Donnell and Bateman, 2005), multimodality (Baldry and Thibault, 2006; Kress, 2003; Kress and van Leeuwen, 2006; Painter et al., 2013), and critical discourse studies (Fairclough, 1992; Martin and Rose, 2003). However, unlike other prominent linguistic theories (Hauser et al., 2002; Petersson and Hagoort, 2012), it has not yet established a mutually beneficial liaison with one of the fastest growing scholarly areas of our time: cognitive neuroscience.

The few contacts between the two arenas, however, have been very promising: in attempting to explore possible neurological correlates of SFL constructs, for example, Melrose (2005, pp. 405–417; 2006, pp. 93–106) has discussed the role of mirror neurons in ideational semantics and relied on neuroimaging evidence for theorizing on the psychobiological foundations of interpersonal semantics, information focus, and theme, among other notions. For their part, García and Ibáñez (2017) have relied on neuropsychological, neuroimaging, and neurophysiological research to show that action verbs (or, to be more precise, 'processes and verbs of doing' in SFL terms) are cognitively different from the participants and nouns they implicate as well as from other process and verb types. Neurocognitive evidence, the authors have argued (García and Ibáñez, 2017, p. 11), would also indicate that fine-grained SFL categories within the 'semantic space' (Halliday and Matthiessen, 2014, p. 86) are naturally grounded in more basic neurocognitive (sensorimotor) distinctions. Also, though perhaps less directly, foundational contributions from Sydney Lamb show that numerous constructs of relational network theory (a framework that informs and is informed by SFL) are compatible with core tenets of brain structure and function (García et al., 2017; Lamb, 1999). Albeit incipiently, these works convergently show that a dialogue between cognitive neuroscience and SFL is possible and desirable, and that insights from the former field can lead to substantial theoretical extensions within the latter.

More interestingly, cross-fertilization between these disciplines can also operate in the opposite direction. As noted in previous works (Butler, 2013; Butler and Gonzálvez-García, 2014), SFL is well equipped to boost research in cognitive neuroscience, as it can "contribute to a more comprehensive programme whose aim is to study the workings of the language user" (Butler, 2013, p. 210). García and Ibáñez (2014), for example, have relied on the notions of field, tenor, and mode to formulate methodological recommendations for language-based brain-coupling research. Moreover, as will be shown below, concrete applications of SFL constructs have led to groundbreaking methodological innovations in the neurocognitive study of language processing (García and Ibáñez, 2018; Trevisan et al., 2017). As demonstrated by these works, the appliable[1] potential of SFL can be expanded beyond its typical scope to forge a new, productive space in the field of experimental design.

More specifically, as will be shown below, SFL provides fine-grained linguistic distinctions cutting across discourse, semantic, morphosyntactic, lexical, and sublexical levels that allow for careful control of experimental materials beyond the typical requisites of single-item designs –a feature that sets it apart from several other theories offering formal accounts of only some of these levels. In addition, with its threefold conception of language in ideational, interpersonal, and textual dimensions, it contemplates features that other formal models typically overlook (e.g., the communicative roles imposed on

[1] The term 'appliable' refers to theoretical notions that can afford practical solutions in specific contexts through a combination of reflection and action (Halliday, 2007 [2002]; Mahboob and Knight, 2010).

interlocutors by specific constructions or the perlocutionary impact of choices concerning the distribution of information within a clause). More generally, the theory seems to bridge the gap between structural descriptions of language and the wider socio-cultural context in which it is used, thus offering a useful framework to meet recent calls for more context-sensitive approaches in cognitive science (Ibáñez and García, 2018). Admittedly, other linguistic theories may also partially meet these imperatives, but that is beyond the point: the usefulness of SFL for informing ecological experimental designs does not hinge on it being the only framework equipped to that end.

Building on these attributes, this paper aims to show that the tradeoff between ecological validity and experimental control, as defined at the outset, can be and has been bridged through the use of SFL. First, we address the main limitations faced by most language experiments in cognitive science. Second, we describe a novel methodological approach, rooted in SFL constructs, which allows designing naturalistic, text-level experimental materials for language research without relinquishing fine control of critical variables. Third, we show how this approach has already been successfully implemented in two original studies aimed to assess direct links between situated experiences and the cognitive systems that mediate language comprehension. Finally, we outline future avenues for developing this approach, thus broadening the horizons of SFL as an appliable theory of language, and, more generally, the prospects for interaction between applied linguistics and experimental language research.

2. Textual naturalness vs. statistical control: a scientific catch-22?

In the last 50 years, experimental research has contributed crucial advances for understanding the relation between language and neurocognition, especially in the fields of psycholinguistics and neurolinguistics. Despite stemming from different traditions, these two disciplines share multiple tenets, goals, and methods, and both have paved the way for theoretical and translational innovations in several fields, as stated at the outset. In particular, they have proven fundamental for understanding the 'building blocks' of language processing, as they allow researchers to carefully control the impact of lurking variables (i.e., potential confounds) and characterize the systems recruited by particular lexico-grammatical categories (e.g., nouns and verbs) or processing levels (e.g., phonological and semantic operations).

For example, if a study aimed to track the specific neural systems subserving verbs and nouns, lists of words from these two categories could be constructed so that they are matched for several important variables known to modulate neurocognitive outcomes (e.g., frequency, length, familiarity, concreteness). This way, differential patterns associated with each category could be reasonably attributed to the verb/noun distinction rather than other differences between the lists. Here lies the crux of stimulus design in the experimental study of language. Yet, this rationale faces a major shortcoming: because the isolated stimuli used in experiments are generally very different from the texts people encounter in their everyday life, there is a dearth of knowledge about the neurocognitive operations at work during discourse-level processing. In other words, we simply do not know whether the core findings of psycholinguistics and neurolinguistics are at all representative of what happens when we face full-blown texts.

A number of studies have addressed this issue in recent years. Desai et al. (2016), for instance, measured neurocognitive and eye-tracking patterns in healthy adults as they read paragraphs from *The Emperor's New Clothes* (by Hans Christian Andersen) and a Nelson-Denny Practice Test. Similarly, Huth et al. (2016) had subjects listen to real-life stories from *The Moth Radio Hour* during an fMRI scanning session. Both studies revealed broad cortical and subcortical activation patterns across anterior and posterior regions of the left and right hemispheres. However, in the absence of statistical control among the structural components of the texts, such designs do not allow establishing firm, confound-free associations between specific linguistic dimensions and putative biological substrates. For example, if neural differences were detected between two (non-manipulated) real narratives, how could one know whether they are mainly driven by graphemic, phonological, lexico-semantic, morphosyntactic, or cohesive factors? Therefore, despite bridging the "naturalistic gap" of the abovementioned approaches, these studies fail to retain their fine-grained control of key variables. The bottom line is that psycholinguistics and neurolinguistics would seem bound by a "scientific catch-22" (Ibáñez and García, 2018, p. 12) between ecological validity and experimental control.

This is where SFL can make a substantial contribution. With its clear-cut categories "above, below and beyond the clause" (Halliday and Matthiessen, 2014, p. vi), the theory seems to offer a rich theoretical framework for researchers to select or construct naturalistic experimental texts while ensuring their quantitative comparability across multiple strata, ranks, and levels. Indeed, as shown elsewhere (García and Ibáñez, 2017), SFL allows refining the interpretation of extant psycholinguistic and neurolinguistic findings through the lenses of well-defined constructs, such as the opposition between processes and participants or the discrimination among different process types. Yet, even more crucially, the theory seems to afford powerful tools for the *creation* of experimental materials that prove both ecologically valid and carefully controlled in terms of multiple variables.

For example, by clearly distinguishing and describing resources both at discourse semantic and lexico-grammar strata, SFL makes it possible to focus on features like transitivity patterns, conjunction, cohesion, substitution, and so on. Of particular interest for the creation of naturalistic experimental materials is the SFL description of inter-sentential relations –i.e., resources 'above the clause'. These comprise clause complex taxonomies and cohesion resources like reference, conjunction, and lexical cohesion (including taxonomic and expectancy relations). These resources, in particular, are crucial for constructing discourse-level materials that are comparable in terms of phonological/graphemic, lexico-grammatical, semantic, and inter-clausal factors, offering a profitable platform for experimental language research to overcome the (seemingly

inescapable) tradeoff between naturalness and atomistic control of text-internal factors. Importantly, this is a problem common to well-established and incipient frameworks at the crossing of linguistics and various branches of cognitive (neuro) science (Ibáñez and García, 2018).

Importantly, rather than a mere promise, the potential of SFL for bridging this gap has actually been corroborated in innovative research. Relevant works have been published by leading journals in cognitive science and neuroscience. In particular, as shown by papers in *Scientific Reports* (Trevisan et al., 2017) and *Cortex* (García et al., 2018), SFL has allowed reaching major milestones to demonstrate that the comprehension of characters' actions in naturalistic narratives crucially depends on the functionality of motor brain regions –and, hence, on each subject's bodily experience (García and Ibáñez, 2017). Below we describe the procedure whereby this finding was made.

3. Overcoming the catch-22 via SFL

3.1. Step-by-step description of the text-construction protocol

Our stimulus-construction protocol comprises nine steps which can be applied (and, if needed, adapted) to operationalize countless fine-grained contrasts among otherwise comparable texts. To obtain materials with those features, researchers should:

1. Construct a number of syntactic patterns (e.g., simple clauses, clause complexes with paratactic relations, clause complexes with hypotactic relations, minor clauses, etc.), devoid of lexical items.
2. Generate one pseudorandomized sequence of such patterns per text (this guarantees that the overall syntactic complexity and variety of all texts will be similar, while preventing facilitation or anticipation effects between successive texts due to similarities in their progressive structural development).
3. Fill the pseudorandomized syntactic patterns with lexical items satisfying the specific lexical, semantic or pragmatic opposition targeted by the research question (e.g., action verbs in one text vs. non-action verbs in another; concrete vs. abstract nouns; literal vs. non-literal expressions; emotionally positive vs. negative words; etc.).
4. Based on validated psycholinguistic databases, obtain quantitative data for all variables representing potential confounds in the prospective results (in extant applications of the protocol, these include: number of characters, words, nouns, adjectives, adverbs, and verbs; mean frequency, familiarity, imageability, syllabic length, and orthographic length for all content words; and measures of comprehensibility, coherence, and cohesion derived from ad hoc normative studies).
5. Check that the texts are suitable for the age-range of the study's samples, and that the ensuing readability scores are matched across texts (automated readability indexes are ideal to this end; for example, the Powers-Sumner-Kearl formula establishes a text's minimum school grade through an algorithm that factors in its number of words, number of syllables, number of sentences, and mean sentence length; whereas the Spache readability formula yields similar information by comparing words in a text with a set list of everyday terms, calculating the word-to-sentence ratio, and establishing the percentage of unfamiliar words in the material).
6. Run appropriate statistical tests for each of those variables across all constructed texts (by default, chi-squared tests for categorical variables and t-tests, non-parametric tests, or ANOVAs for quantitative variables, depending on the number of texts and the distribution of the data for each variable);
7. If specific variables are not statistically matched, replace specific lexical items in individual texts seeking to achieve the desired comparability while preserving coherence, cohesion, and idiomaticity in each text.
8. Having performed such changes, rerun the statistical tests described in point 6 above (this step should be repeated until the desired balance is achieved).
9. If necessary, design a multiple-choice questionnaire for each of the texts with questions pointing at the units or information type being investigated (ideally, the items included in the questionnaires should point to contrasting conditions within and across texts; also, response options in the questionnaire should be pseudorandomized within each item to avoid attentional or positional biases in the responses).

By way of illustration, the following section shows how this protocol has been successfully implemented in two individual studies to address a specific question that has become a hotspot of research in psycholinguistics and neurolinguistics: the relationship between bodily experience and the comprehension of action verbs.

3.2. Applying the protocol to a specific research question: tapping the link between bodily experience and action semantics through naturalistic narratives

One of the hotspots of research in psycholinguistics and neurolinguistics concerns the relationship between language and bodily experience, a link that has been established in studies examining so-called action verbs –i.e., verbs that denote bodily movements (García et al., 2019; Pulvermüller, 2013a,b; Pulvermüller, 2018). This connection has been supported by experiments measuring (i) brain activation levels, (ii) performance in patients with motor-network damage, and (iii) action

execution speed in behavioral tasks. Specifically, relative to other word classes, action verbs have been shown to increase activation levels in motor cortices (Hauk et al., 2004; Tomasino et al., 2007, 2008), become impaired upon damage to such regions (Birba et al., 2017), and accelerate or delay the execution of overt actions (García and Ibáñez, 2016). Importantly, these effects prove selective for action verbs (there being no comparable outcomes during processing of nouns realizing event participants), suggesting that the SFL distinction between processes/verbs and participants/nouns is neurocognitively plausible (García and Ibáñez, 2017). Moreover, these findings indicate that language processing partly consists in reactivating the circuits mediating the situated experiences denoted by the wording at hand, a conclusion that has been used to extend the stratificational structure of SFL through the interpolation of a new conceptual layer (the sensorimotor level) between the classical contextual and semantic strata (García and Ibáñez, 2017).

Taken together, the above evidence suggests that these verbs are differentially grounded in motor brain networks –namely, neural circuits specialized in the planning, execution, and monitoring of bodily actions (Pulvermüller, 2013a,b). This supports the view that, to a large extent, language processing consists in reactivating the circuits mediating the situated experiences denoted by the wording at hand. Yet, despite their usefulness for the development of clinical (García and Ibáñez, 2018) and educational (Macedonia and Mueller, 2016; Macedonia et al., 2010, 2011) innovations, virtually all of these findings have been obtained through atomistic research designs, as defined in the previous section. Note, in this sense, that specific neurocognitive patterns detected during single-item tasks cannot be *a priori* assumed to hold during ecological discourse-level processes subsuming multiple operations, such as word access, syntactic parsing, semantic integration, and memory retrieval. Indeed, contextual information can modulate action-word processing (García and Ibáñez, 2016; van Dam et al., 2010) and facilitate verbal outcomes by favoring maintenance of relevant information (Ledoux et al., 2006). Moreover, contextual cues can even enhance cognitive performance in neuropsychiatric conditions (Aviezer et al., 2009; Ibáñez et al., 2016). Therefore, the detection of similar effects between token-level and discourse-level tasks would represent an empirical breakthrough with the potential to extend and refine relevant theories (Trevisan et al., 2017) and inspire new translational applications (García and Ibáñez, 2016, 2018).

This scenario prompts a pivotal question: does motor-network resonance also mediate our processing of action verbs when we deal with naturalistic discourse? In two recent studies (García et al., 2018; Trevisan et al., 2017), SFL was used to provide the first systematic assessment of this question by developing carefully balanced naturalistic narratives differing exclusively in their degree of action-related content. Specifically, the aim was to explore whether comprehension of action verbs was differentially related to motor-system activity in context-rich, coherent, and cohesive stories. Below we describe the step-by-step procedure by which we traversed this new appliable horizon of the theory.

We created four simple stories, each of them narrating a day in the life of particular fictional characters. Each text featured 32 verbs. Two of these texts were called 'action texts' (ATs) and the other two were termed 'neutral texts' (NTs). First of all, to ensure structural comparability among the texts, we designed eight syntactic patterns based on systemic-functional categories, which were later filled with specific lexical items. By way of example, one of the patterns was "Clause complex: clauses in paratactic relation (extension: addition)", with the following internal structure: [clause complex [clause 1: subject + verb + complement/s] [coordinator: 'and'] [clause 2: elliptic co-referential subject + verb + complement/s]]. This pattern was filled as "He gave him the money and added some more coins" for one AT, and as "He was extremely happy and had many friends" for one NT – note the deliberate choosing of action verbs for the first sentence, and processes/verbs from other categories (in this case, relational processes/verbs) for the second one.

As a result, all four texts featured very similar numbers of clauses, simple clauses, clauses with paratactic relations only, clauses with hypotactic relations only, clauses with both paratactic and hypotactic relations, and minor clauses (see Table 1). This ensured that possible differential outcomes for each text type could not be attributed to discrepant syntactic demands between them. Moreover, all the grammatical patterns thus created were then pseudo-randomly distributed within each text to minimize the possibility of anticipation and/or priming effects in the second condition.

Once these syntactic patterns were organized, they were filled with verbs satisfying the action vs. non-action opposition and additional words. Crucially, over 70% of the clauses in the ATs comprised action verbs, describing physical activities (as in the first example sentence transcribed above). By contrast, more than 80% of the clauses in the NTs included other process/verb types (mainly mental and relational ones), which implied no physical action (as in the second example sentence above). The opposition between action verbs and neutral verbs was established according to semantic, syntactic, and distributional criteria proper to SFL. First, all action verbs were canonical examples of an SFL category termed 'processes of doing' –a predominant subset of so-called 'material processes' (Halliday and Matthiessen, 2014: 179) –, whereas all non-action verbs were canonical examples of other SFL categories, such as mental, verbal, behavioral, and existential processes (Halliday and Matthiessen, 2014: 197–306). Second, in making these choices, we ensured that all chosen verbs complied with the distinguishing structural and semantic constraints of the corresponding SFL categories. For example, in their 'unmarked' form, verbs of doing typically occur in the present continuous tense, whereas others, like mental ones, typically occur in the simple present form; also, processes of doing do not generally allow speakers to construe the same situation by using antonymic verbs and reassigning participant roles while preserving the same voice (e.g., "Mary enjoyed it" can be reconstrued as "It pleased Mary", but no such rewording is possible for "James punched it"); in addition, mental processes can set up another clause as the content of thinking (projection), whereas processes of doing, as well as relational and behavioral ones, cannot; moreover, processes of doing, like others, can involve only one participant, whereas relational ones, for example, need at least two; finally, processes of doing require participants endowed with consciousness, but this is not the case for relational ones, for instance. All these restrictions were observed in the selection of verbs for each category and in the construction of the

Table 1
Linguistic features of the action and neutral texts (adapted from Trevisan et al., 2017). The key manipulated variables across texts are identified in bold case.

	AT1	NT1	AT2	NT2	*p*-value
Characters[a]	696	743	693	668	0.241[#]
Words	167	169	164	153	0.816[#]
Nouns	33	25	28	22	0.485[#]
Adjectives	6	14	5	14	0.058[#]
Adverbs	6	16	9	10	0.161[#]
Verbs	**32**	**32**	**32**	**31**	**0.999[#]**
Action verbs	**25**	**11**	**25**	**9**	**0.004[#]**
Non-action verbs	**7**	**21**	**7**	**22**	**0.002[#]**
Mean content word frequency[b,c]	803	974.6	926.4	1014	0.857*
Mean content word familiarity[b,d]	593.2	582.4	598.6	598.3	0.419*
Mean content word imageability[b,e]	442.8	394.9	440.2	399.1	0.060*
Mean content word syllabic length	1.3	1.5	1.3	1.4	0.156*
Mean content word orthographic length[b]	4.8	5.1	4.8	4.8	0.680*
Sentences	17	17	17	17	0.999[#]
Minor sentences	0	0	0	0	0.999[#]
Sentences with parataxis only	3	3	3	5	0.835[#]
Sentences with hypotaxis only	4	3	3	1	0.630[#]
Sentences with parataxis and hypotaxis	3	3	4	2	0.881[#]
Coherence	3.7	3.6	2.75	4	0.471*
Reference	25	14	21	20	–
Conjunction	5	3	4	3	–
Lexical cohesion: Expectancy	5	2	2	4	–
Lexical cohesion: Classification (similarity)	3	9	4	3	–
Lexical cohesion: Composition (meronymy)	3	3	5	4	–
Comprehensibility	3.9	3.6	3.25	4	0.619*
PSKF	4.4	4.55	4.22	4.39	–
SRI	3	2.8	3.5	2.7	–

Notes. PSKF: Powers-Sumner-Kearl Formula; SRI: Spache Readability Index (revised). [a] Character count was performed without counting spaces. [b] Psycholinguistic data was extracted from N-Watch (Davis, 2005), based on lemma counts. [c] Frequency data was extracted from the CELEX written database, through N-Watch (Davis, 2005). [d] Familiarity data was extracted from the MRC database, through N-Watch (Davis, 2005). [e] Imageability data was extracted from the Bristol/MRC database, through N-Watch (Davis, 2005). [#] *p*-values calculated with chi-squared test. [*] *p*-values calculated with independent measures ANOVA. AT: action text; NT: neutral text. Adapted from Trevisan et al. (2017). A moving story: Whole-body motor training selectively improves the appraisal of action meanings in naturalistic narratives. *Scientific Reports* 7 (1): 12538. https://doi.org/10.1038/s41598-017-12928-w. Authorized reproduction under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).

clauses in which they occur within the texts. By observing these constraints, we ensured that the action vs. non-action opposition was robustly operationalized in the experimental materials (see Table 1).

All texts were also carefully matched for other relevant variables. First, they all presented almost identical numbers of characters, words, nouns, adjectives, adverbs, and verbs. Second, the mean frequency, familiarity, syllabic length, orthographic length, and imageability of content words were statistically analogous across the texts –psycholinguistic data for all lexical items were extracted from the N-Watch software (Davis, 2005). Third, we made sure that the number of cohesive markers (indicating reference, conjunction, and lexical cohesion) was also matched across narratives. This allowed us to rule out the possibility that potential differences in the comprehension of ATs and NTs were driven by graphemic, lexical, semantic, or cohesive factors other than the action vs. non-action contrast targeted in the design (see Table 1).

The resulting texts were further assessed in terms of coherence and comprehensibility. To this end, we asked 20 adult readers to complete an online rating study in which the constructed texts were presented separately, and each of them was followed by two questions: one on cohesion ("How coherent was this text to you?") and another one on comprehensibility ("How comprehensible was the text to you?"). In both cases, responses were provided on 5-point Likert scales ranging from 1 (fully incoherent/incomprehensible) to 5 (perfectly coherent/comprehensible). Finally, the texts' readability was controlled by means of three automatized indexes: the Powers-Sumner-Kearl Formula, the Spache Readability Index, and the Inflezs scale (see Table 1).

All in all, this resulted in carefully controlled texts, which were matched along multiple critical variables while differing specifically in their proportion of verbs/processes of doing and other types of verbs/processes. Crucially, the narratives were fully coherent and cohesive and had no overt signs of any of these manipulations. Therefore, in the eyes of the participants, they proved as natural as any other story they could encounter in daily life. By way of illustration, Table 2 shows an example of each text type.

Then, to assess comprehension in the actual experiments, we created a multiple-choice questionnaire for each narrative. Half of the questions in each questionnaire pointed to information evoked by verbs and verb phrases, and the other half pointed to circumstances (for example, units denoting locative or temporal information) explicitly realized by prepositional phrases or adverbs. For example, the question "What did Tommy do with some more coins?" pointed to process-related information realized by an action verb, while the question "Where did Donald look for his money?" pointed to circumstantial information realized by a prepositional phrase. In the AT questionnaire, all process-related questions referred to

Table 2
Examples of the action and neutral texts created for the experiments.

Action Text 1	Neutral Text 1
Donald looked into his bag for his money, but it was not there. Had someone taken it from him? He moved back and forth thinking what to do. He ran to his friend Tommy's house to take the money he had left there. Tommy was working when Donald rang the bell. He gave him the money and added some more coins. Donald counted the lot in great exultation. Soon after, he went to the newspaper office. He put his money and his coins on the table and asked the receptionist to put an ad in the newspaper the next day. "I have lost my moneybag. If you find it, please call me!", the ad said. When Donald got up the next day, a man came to his house. He had found the moneybag! Donald thanked the kind man and jumped with exultation. To show his appreciation, he took the man to a bar and they had breakfast together. What a great time it was! Donald had found his moneybag!	Poppy lived in a very nice village. The inhabitants there were really nice and supported each other. He was extremely happy and had many friends. However, the inhabitants were very frightened by chocolate. "If you eat it, you'll be very sick", a girl said. He thought about this in great curiosity. Was that really true? To find out, he started a journey towards a nearby village, and asked the people there. They found his doubts quite funny and offered him to try some different flavours. How much he loved them! It seemed now difficult to believe the things his friends had told him. During his days there, he ate a lot of chocolate but he never felt sick. He knew the truth now! His friends had believed in a lie when that stranger had come to town. When he went back to his village, he brought a lot of chocolate. He was very proud of himself now. He spent a lot of days teaching people what to believe in.

action verbs; in the NT questionnaires, all process-related questions pointed to processes/verbs from other categories. Therefore, action-information questions had a contrastive condition within and across texts. Questions followed the order of the corresponding events in the texts and they were sequenced with a strict alternation between process-related and circumstantial items. Each question had five options, namely: a fully correct response, a subtly incorrect response, an exaggeratedly incorrect response, a ridiculous response, and an 'I don't remember' option. The options' order was randomized across questions, except for the 'I don't remember' option, which was always presented last (for examples, see Fig. 1). Correct responses would be given 1 point, while incorrect responses and the "I don't remember" option yielded 0 points (see Fig. 1).

The outcomes were used to establish the level of comprehension and retrievability of action versus non-action information. Raw scores were then added, per participant, for the process-related and circumstantial questions in the action and the neutral texts. Those aggregated scores were then averaged within each group of participants and subjected to statistical analyses via specific ANOVAs,[2] and significant interactions were inspected via Tukey's post-hoc tests.

In short, thanks to the use of formalized constructs from SFL, this protocol seems to help circumventing the "scientific catch-22" described above. In particular, by relying on this theory, we were able to construct narratives which are both carefully matched and differentiated in terms of one dependent variable –namely, action-load (Table 1)–, while ensuring their naturalness, coherence, and cohesiveness (Table 2) as well as their empirical informativeness for within- and between-text analyses (Fig. 1). More crucially, the usefulness of this applied development has been corroborated in two separate studies, as detailed below.

A. Example of question pointing to process-related information

What did Tommy do with some more coins?	1. He added them
	2. He lent them to Donald
	3. He cleaned them
	4. He burned them
	5. I don't remember

B. Example of question pointing to circumstantial information

Where did Donald look for his money?	1. In his bag
	2. In his drawer
	3. In his car
	4. At the airport
	5. I don't remember

Fig. 1. Example of questions pointing to process-related or circumstantial information.

[2] Given that the study by Trevisan et al. (2017) involved a one-sample pre/post design, data were analyzed via a 2 × 2 × 2 factorial ANOVA including three factors: text type (ATs and NTs), information type (process-related and circumstantial), and time point (Pre-T and Post-T). On the other hand, the experiment by García et al. (2018) involved comparisons between patients and subjects, so that each text (AT and NT) was subjected to a 2 × 2 repeated-measures ANOVA comprising two factors: group (patients and controls) and information type (process-related and circumstantial).

4. Applying the materials in actual studies

The materials detailed above were first reported in an innovative study conducted in Australia. Also, the same text construction protocol was used to create analogous materials in Spanish for another experiment carried out in Colombia. The goal of both studies was to assess the role of motor systems in action-verb comprehension, thus offering a direct testing ground for the expanded stratificational framework advanced by García and Ibáñez (2017) for SFL modelling.

The Australia study involved 20 English-speaking dyslexic children. The aim of the experiment was to examine whether systematic bodily training, via an ecological and engaging physical activity, could distinctively boost comprehension of action verbs in the naturalistic narratives presented above (Trevisan et al., 2017).

Participants were initially asked to listen to an AT and a NT twice, and to fill in the corresponding questionnaire right after each text. After that, they were asked to play immersive, whole-body video games for 9 days (90 min a day) using a Nintendo Wii console. The required movements had to be fast and precise, so that children could either avoid or interact with moving objects and characters in transient events. After the 9-day training protocol was over, the children listened to the AT and the NT which had not been used before, and they were administered their corresponding questionnaires (Fig. 2, panels A1 through A3). In line with García and Ibáñez's (2017) extended stratificational model, the underlying hypothesis was that systematic whole-body training should lead to a selective increase in the comprehension of action verbs.

Results showed that, by the end of the 9-day protocol, children exhibited an improvement in the comprehension of process-related information in ATs (i.e., action verbs). Crucially, no such enhancement was observed in the comprehension of processes/verbs in the NTs or circumstantial information in any of the two texts (Fig. 2, panels B1 through B3). Therefore, the processing advantage for action verbs did not spread over to information coded through non-obligatory adverbial or prepositional phrases, arguably because these categories do not hold any necessary semotactic and lexotactic links to such processes/verbs (Trevisan et al., 2017). In other words, within the context of this specific experiment, discourse-level improvements triggered by whole-body activation seemed confined to the space of action verbs, as opposed to the overall semantic structure of ATs. Although its generalizability to other domains and settings remains to be tested, this finding constitutes unprecedented evidence of a specific link between sensorimotor mechanisms and congruent lexico-semantic categories embedded in naturalistic texts (see Fig. 2).

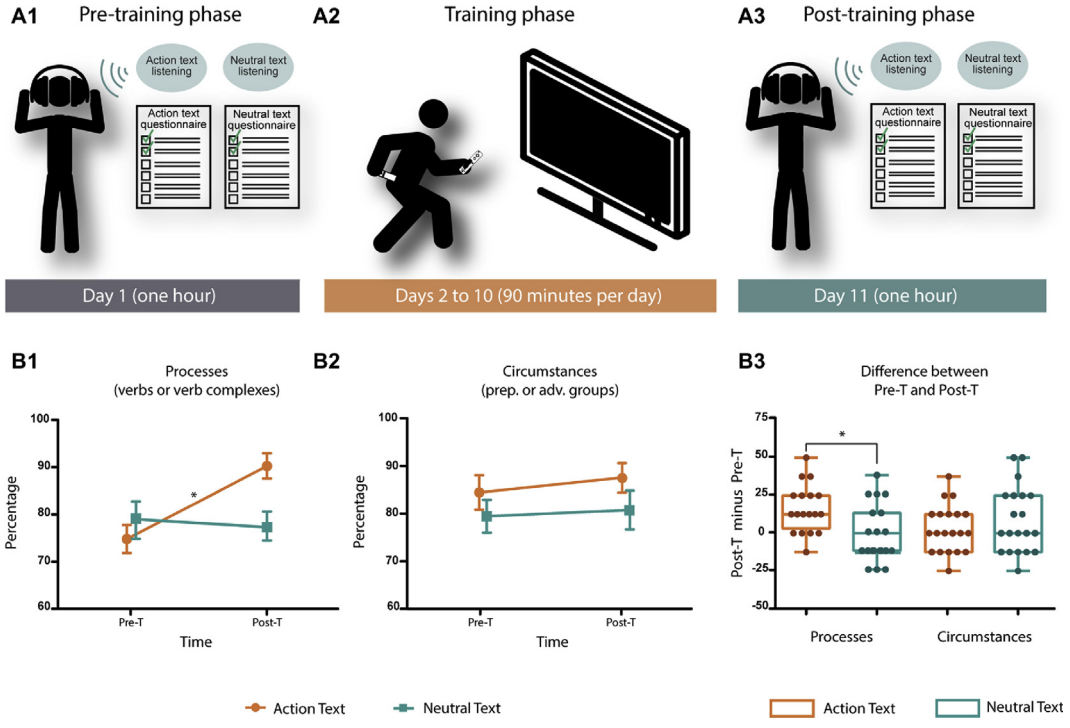

Fig. 2. Narrative comprehension following whole-body training. **A.** Study design. **A1.** Pre-training phase. **A2.** Training phase. **A3.** Post-training phase. **B.** Results. **B1.** Comprehension of processes/verbs of doing increased significantly only for action texts after bodily training. **B2.** Comprehension of circumstantial information was unaffected by bodily training in both action and neutral texts. **B3.** Subtraction analyses corroborated that bodily training selectively enhanced comprehension of processes/verbs of doing. Values on the Y-axes indicate percentage scores. Asterisks (*) indicate significant differences. Pre-T: pre-test phase; Post-T: post-test phase. Reproduced from Trevisan et al. (2017). A moving story: Whole-body motor training selectively improves the appraisal of action meanings in naturalistic narratives. *Scientific Reports* 7 (1): 12538. https://doi.org/10.1038/s41598-017-12928-w. Authorized reproduction under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).

The Colombia study included 40 Parkinson's disease (PD) patients and 40 healthy volunteers matched for age, sex, and education level. Given that PD patients are mainly characterized by movement disorders and motor-network atrophy (García and Ibáñez, 2017), it was hypothesized that their text comprehension skills would be characterized by a distinctive deficit for grasping action verbs (García et al., 2018).

This protocol involved only one AT and one NT, both in Spanish. Participants were first asked to silently read each story at their own pace, and later complete the corresponding questionnaire.

The most compelling results belonged to a subset of PD patients who featured a well-preserved cognitive status –specifically, patients who gave no signs of mild cognitive impairment, based on the validated Montreal Cognitive Assessment (Gill et al., 2008). This subsample presented significant difficulties in comprehending information manifested by action verbs, in the absence of any deficits for grasping processes/verbs in the NTs and circumstantial information in either text (Fig. 3, panels A and B). Importantly, those impairments remained significant even when controlling for general cognitive dysfunctions, which indicated that they represented a primary deficit rather than a secondary consequence of unspecific domain-general disturbances. Moreover, such a selective disturbance allowed classifying individual patients and controls with an accuracy of 83% –a precision higher than that obtained via a sensitive executive battery, namely the IFS test (Torralva et al., 2009) (Fig. 3, panel C). Briefly, this study represents the first-ever demonstration that motor-network integrity is specifically crucial for understanding action-related information in naturalistic narratives, further indicating that this neurocognitive relation is potentially selective, primary, and robust at a subject-by-subject level. Therefore, beyond its theoretical consequences, this study attests to the potential benefits of including sensitive discourse-level tasks in clinical screening protocols for motor diseases (Birba et al., 2017) (see Fig. 3).

Taken together, both studies offered crucial evidence regarding the key role of sensorimotor mechanisms for grounding action information (namely, action verbs) in naturalistic narratives. Also, and more crucially for present purposes, they stand as a concrete illustration of a powerful appliable niche for SFL: the text-construction protocol anchored in this theory proved instrumental to circumvent an apparent methodological dead-end constraining psycholinguistic and neurolinguistic

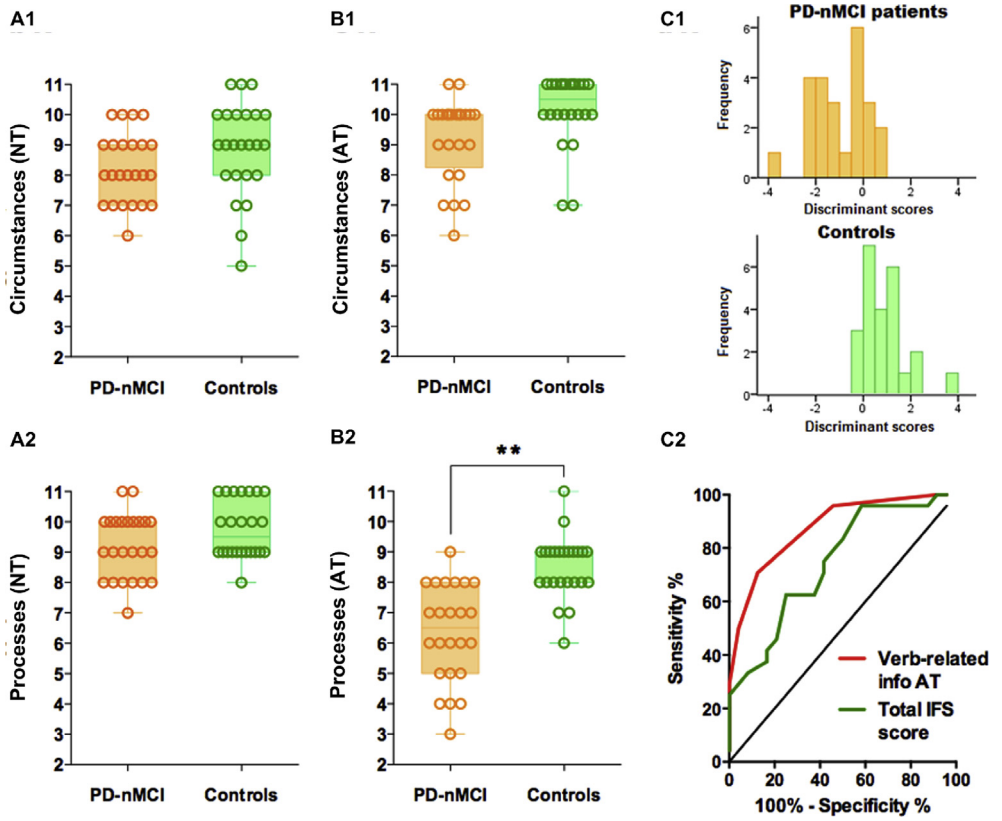

Fig. 3. Narrative comprehension in Parkinson's disease patients without MCI (PD-nMCI) and healthy controls. **(A1, A2)** Neutral text (NT): comprehension of circumstances and non-action processes. **(B1, B2)** Action text (AT): comprehension of circumstances and processes of doing. Asterisks identify significant differences after adjusting for general cognitive state. **(C1)** Distribution of discriminant scores for PD-nMCI patients and controls. **(C2)** ROC curves for appraisal of action processes and executive-function scores. Reproduced from García, A. M., Bocanegra, Y., Herrera, E., Moreno, L., Carmona, J., Baena, A. […] & Ibáñez, A., Parkinson's disease compromises the appraisal of action meanings evoked by naturalistic texts, *Cortex*, 100, 111–126, Copyright 2018, with permission from Elsevier.

research. Below we discuss the implications and prospects of this promising avenue for developing the translational potential of SFL.

5. Discussion

Despite proving crucial for neurocognitive investigations, psycholinguistics and neurolinguistics are undermined by poor ecological validity –i.e., the degree to which tasks reflect the conditions of everyday communication. Indeed, whereas verbal processing in real life is based on unfolding, context-rich texts characterized by cohesion and coherence, experimental language research has nearly exclusively relied on the presentation of disconnected, decontextualized items. As stated earlier, this reflects a long-standing tradeoff between ecological validity and experimental control, with most experiments being built on the assumption that the latter can be achieved only at the expense of the former. Here we have argued that this tension can be effectively undone, further specifying how this can be (and has been) done through the notional toolkit of SFL.

SFL has always defined itself as an appliable theory (Halliday, 2002; Matthiessen, 2012) and its potential for expansion has been successfully tested in various settings over the last 50 years, including the development of syllabi and curricula within the educational arena (Martin and Maton, 2013; Martin and Rose, 2008; Rose and Martin, 2012) and programmes for community-oriented action in healthcare settings (Matthiessen, 2013). The present work shows that the appliable potential of the theory can be manifested not only in the description and analysis of verbal materials, but also in the creation of new texts satisfying particular constraints. In this sense, we contend that the applications of SFL are also relevant to tackle a critical problem facing experimental language research.

Importantly, the methodological contribution described in this article also bears interpretive consequences: crucially, by controlling or accounting for all these factors in the construction of (comparable) texts, this methodological framework allows ruling out multidimensional factors as possible confounds influencing the outcomes of the experiments. In other words, by matching key properties of the texts along all these variables, researchers can justifiably attribute detected effects to their key manipulated variable.

Note, at this juncture, other theories of language have long been employed with similar ends. For example, Generative Grammar has been used in a number of experiments tagging the neural basis of different language categories. For instance, the works by Brennan et al. (2012) and Brennan et al. (2016) have used passages from *Alice in Wonderland* to assess neural correlates of syntactic structure building, while Bachrach (2008) targeted correlates of different sentence types within journalistic, historical, and fictional narratives to delineate a neural model of grammatical competence. However, none of these studies has implemented deliberate manipulations to isolate or control for any specific variable while ensuring comparability among different texts, so that their results cannot be attributed to any fine-grained linguistic factor distinctively manifest in a given piece of discourse. Therefore, such works satisfy the imperative of ecological validity but they fall short of offering the statistical comparability needed to overcome the "scientific catch-22" described above. In this sense, our text-construction protocol objectively achieves a core methodological aim (creating comparable naturalistic texts) that escapes the scope of these antecedents.

This underexplored line of work broadens the interdisciplinary scope of SFL through scalable synergies with experimental language sciences. So far, such an interaction has been limited to the use of psycholinguistic and neurolinguistic findings to test the cognitive plausibility of SFL constructs (García and Ibáñez, 2017; Melrose, 2005, 2006) and outline possible specifications within the theory's broad architecture. The work presented in this paper therefore stands as tangible proof that the very notion of 'appliability' in SFL can be expanded beyond its typical horizons and projected onto the realm of experimental stimulus design in psycholinguistics and neurolinguistics.

The new spaces thus created for the transferability of expert linguistic knowledge could expand the spheres of action of SFL scholars. In addition to language description, teaching, and education, students and professional in the SFL community may perhaps find new outlets by joining interdisciplinary teams in experimental language science. To this end, specific courses could be devised to equip students with systematic competences in the construction of carefully controlled but still naturalistic discourse-level materials.

Looking forward, this prospective line of work could keep growing and lead to novel contributions for experimental language research. First, similar stimulus-construction strategies could be used for analyzing the neurocognitive underpinnings of other discourse-level phenomena, by manipulating different types of processes (e.g., mental, relational, existential) and participant roles (e.g., agents, recipients, targets) across texts. Also, sentence structure, which is often confounded with sentence-level meaning, could be manipulated in terms of relevant SFL notions to disentangle the effects of lexico-grammatical and semantic processes. Specifically, minimal adaptations to the text-construction protocol described here could allow creating texts conveying the same ideational information via deliberatively contrastive sentence structures (one text could involve only simple clauses, another one could consist only of paratactic clauses, and yet another one could be composed of hypotactic clauses). Also, research on cohesion could strategically manipulate relevant lexical (e.g., repetition, synonymy, meronymy) or grammatical (e.g., reference, ellipsis, substitution, conjunction) resources to examine key signatures of the phenomenon. Likewise, additional progress could be attained by creating contrastive texts specifically aimed to assess, for instance, processing of grammatical metaphors or information dislocated in theme-rheme chains. In the same vein, highly controlled text pairs could be built that differ in the degree of non-literalness (for instance, a study on correlates of irony could rely on a given story that is narrated literally in one text and ironically in another one). More ambitiously, our text-construction protocol could be adapted to be used in interactive, language-based experiments focused on the interpersonal

metafunction. As proposed elsewhere (García and Ibáñez, 2014) controlling the configuration of tenor during dialogical tasks could help improve our knowledge of inter-brain communication in multi-participant experimental settings.

Admittedly, however, future implementations of our protocol will need to address its present limitations. First, constructing comparable texts is very time consuming: the texts reported in the present studies required roughly 4 months to be built (indeed, to achieve four comparable texts, at least twice as many need to be constructed and validated so that at least half of them will, ideally, prove similar across all relevant variables. Second, the materials created with this approach will be fully language-specific: given the syntactic patterns created and the lexical choices made, the textual structures created cannot be directly extrapolated to other languages. Moreover, the length of the texts has to be kept relatively short in order not to burden the participants –a concern that proves even more pressing in patient studies. Therefore, the questionnaires based on the texts can only include a relatively small number of items, which could undermine statistical power and fail to capture sufficient variability within and between samples. Finally, in the studies published so far text-comprehension data were gathered offline, in the absence of real-time neural signatures. However, in line with previous works (Desai et al., 2016; Huth et al., 2016), the texts could be used in online neuroimaging protocols tracking neural modulations locked to specific items of interest within the texts, among other possibilities. Importantly, notwithstanding the shortcomings noted here, the robustness and reliability of extant results across different populations and in two different languages attest to the sensitivity and flexibility of the protocol, suggesting that its continued application can result in further empirico-theoretical breakthroughs.

In sum, considering the relevance of these types of studies both for linguistics and for cognitive science, it is desirable that collaborations like the ones described here might be strengthened: once language-oriented experiments become more systematically informed by comprehensive, text-sensitive theories, ensuing outcomes can prove very useful for theoretical and applied developments in both disciplines. It is our hope that the work presented herein represents a stepping stone in that direction.

Author contribution statement

This article is a joint production and reflects the work and views of both authors. Sections 1, and 2 have been jointly authored. Section 3 was composed by PT and sections 4 and 5 were written by AMG.

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