

Language-Specific Mappings from Semantics to Syntax

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Abstract

We present a study of the mappings from semantic content to syntactic expression with the aim of isolating the precise locus and role of pragmatic information in the generation process. From a corpus of English, French, and Portuguese instructions for consumer products, we demonstrate the range of expressions of two semantic relations, GENERATION and ENABLEMENT (Goldman, 1970) in each language, and show how the available choices are constrained syntactically, semantically, and pragmatically. The study reveals how multilingual NLG can be informed by language-specific principles for syntactic choice.

1 Introduction

We report here on work which addresses the message-to-syntax mapping in the context of automatic generation of instructional texts - the kinds of texts found in the procedural parts of manuals or information leaflets. pharmaceutical products. Instructional texts do not simply consist of lists of imperatives: instructions may also describe, eulogise, inform and explain. Generating good-quality draft instructions requires a detailed specification of how to map from semantic representations of the task actions onto a wide range of linguistic expressions.

Our corpus is composed of naturally-occurring instructions in the three languages of study. Our overall approach is to obtain different-language drafts that are *congruent* with the technical content embodied in the task to be performed (and with other relevant information about the task). A satisfactory level of congruence requires the use of syntactic and pragmatic rules appropriate to *each* target language, mapping from the semantics to appropriate expression in a way that is free from influence from any source language¹. We

¹See (Hartley and Paris, 1995) for discussion of the

begin the generation process with a plan-based model of the underlying task.²

In our study, we have looked at two specific procedural relations that can hold between pairs of actions in a task, identified by the philosopher Alvin Goldman as the relations of GENERATION and ENABLEMENT (Goldman, 1970) relations which have the advantage of being formally specified (see e.g.(Pollack, 1986; Balkanski, 1993)), and need to be expressed regularly within instructional texts. In section 2, we give a brief definition of generation and enablement, before going on in section 3 to describe how the two relations are realised in the corpus of Portuguese, English, and French instructions.

2 The Semantic Relations

Generation and enablement are relations that can hold between pairs of states, events, processes, or actions. A simple test of generation holding between action pairs is whether it can be said that by performing one of the actions (α) under appropriate conditions, the other (β) will automatically occur (Pollack, 1986). If so, it can be said that α generates β . The two actions must be performed, or perceived to be performed, by the same human agent, and the two actions must be asymmetric (i.e. if α generates β , then β cannot generate α). Simple examples of generation are as follows:³

- (1) Heat gently to soften the coating.
- (2) Dial the numbers of the Mercury authorisation code by pressing the appropriate numbers on the keypad.

In example 1, the action of heating gently has the effect of softening the coating. In example 2,

advantages of this approach over the inherent limitations of a translation-based approach to producing multilingual instructions.

²See (Paris et al., 1995) for a discussion of the modelling of domain knowledge for instructions in the context of a support tool for drafting instructional texts.

³So far, we have concentrated on examples of these semantic relations that do not cross sentence boundaries.

pressing the correct keypad numbers has the automatic effect of dialing the numbers of the Mercury authorisation code. In each case, by performing the α action (or set of actions), the user has automatically performed the β action. Note that the two actions can be presented in either order: generatING first, or generatED first.

The term enablement is commonly used to refer to the procedural relation between preconditions and actions. It obtains between two actions where the execution of the first *brings about a set of conditions that are necessary, but not necessarily sufficient* for the subsequent performance of the second (Pollack, 1986). This is different from the generation case, since enablement requires the further intervention of an agent - and it need not be the same agent - to bring about the β eventuality.

- (3) Close cover and test as recommended in 'Operation' section.
- (4) For prolonged viewing, the slide may be pushed downwards and then backwards until it locks under the ledges at each end of the slot.

Example 3, taken from the instructions for a household smoke alarm, shows the enabling action appearing first: closing the cover enables testing to take place, but does not automatically result in a test. Example 4, from the instructions for a home photographic slide viewer, presents the enabled action - prolonged viewing - first, and describes to the user what must be done to facilitate it.

These two relations have been formalised by Pollack (1986) and Balkanski (1993) for the purposes of plan recognition, and can be represented in a plan formalism that is a simple extension of STRIPS-styled operators developed by Fikes (1971) and expanded in the NOAH system (Sacerdoti, 1977). Here, we summarise the two relations in the form of the following planning statements:

- α generates β iff α is the body of a plan ϵ whose goal is β .
- α enables β if α is a precondition of a plan ϵ and β is the goal of plan ϵ , or if β is the body of ϵ and α is a precondition of β .

In order to generate instructions clearly, it must be obvious which, if either of the two relations is intended at any given point: confusion of one with the other will lead to inadequate, incomplete, or even dangerous execution of the task described.

3 From Semantics to Syntax

How, then, are generation and enablement realised in the three languages of study? In what follows, we look at the syntactic resources that are used in each language to convey the two parts of the two relations, and look at the constraints

on the ordering of the two parts; then, at what discourse markers play a role in further ensuring the clarity of the relation intended, and finally show how different rhetorical interpretations result from these choices. Together, these factors explain a significant amount of the cross-linguistic variation that occurs within the instructions sub-language. In what follows, however, it is not our intention to suggest an ordering for the set of decisions that need to be made for generation: so far, our research suggests a complex interaction of factors is involved in choice of expression, and further research is required to establish their relative priorities in the decision-making process.

Our corpora for the study consisted of 65 examples of generation, and 65 examples of enablement for each of the three languages of study.⁴

3.1 Syntactic Resources

The distribution of expressions among the two components (ED and ING) of the generation relation for Portuguese is shown in figure 1⁵.

Syntax	GeneralED			GeneralING			%
	1st	2nd	Total	1st	2nd	Total	
Infinitive	23	27	50	3	9	12	47.8
Imperative	0	0	0	26	19	45	34.6
Passive	2	0	2	3	2	5	5.4
Subjunctive	4	1	5	0	0	0	3.8
Nominal	1	4	5	0	0	0	3.8

Figure 1: Expressions of Generation: Portuguese

Three strong patterns emerge in the data. First, two syntactic forms, infinitives and imperatives, dominate; together they account for over 80% of the action expressions in the data set. Second, the overlap in expressions between ED and ING elements is relatively small; it is confined to only two of the five types of expressions: infinitives and passives. Finally, these data suggest that the order of occurrence of the ED and ING components in a sentence does not interact with decisions of choice of expression: in general, once a syntactic form is made available for expressing ED or ING components, it can be used irrespective of the order of occurrence of that component in the sentence.

French (see figure 2) shows a strong preference for the use of the two forms of imperative (imperative-simple and imperative-infinitive), the infinitive and the gerundive. Overall, however, there is a more even spread between choices than

⁴In order to satisfy ourselves that the linguistic examples in the corpus were indeed representative realisations of the two semantic relations described, we also performed an experiment requiring naive informants to identify linguistic examples as cases of one or other relation. There was a high degree of agreement on what constituted an example of each.

⁵This includes only those syntactic categories for which we found more than one example in the data set; for this reason the percentages do not total to 100.

that appearing in Portuguese.

Syntax	GeneratED			GeneratING			%
	1st	2nd	Total	1st	2nd	Total	
Imp've-Infin.	15	0	15	13	5	18	25.4
Infinitive	8	17	25	0	0	0	19.2
Gerundive	0	0	0	0	25	25	19.2
Imp've-Simple	7	0	7	10	5	15	16.9
Finite	3	6	9	0	1	1	7.7
Nominal	2	0	2	3	3	6	6.2

Figure 2: Expressions of Generation: French

French, unlike Portuguese and English, has two forms of imperative. One is identical in form to the infinitive of the verb and is usually associated with a generic addressee: a 'public' form of address. The imperative-simple, on the other hand, is identical in form to the second-person plural⁶ indicative of the verb and its use is associated with identifiable addressees. The fact that this form accounts for 40% of imperatives in the corpus may be seen as evidence for the increasingly user-oriented style of instructions for household appliances.

Unlike in Portuguese, ordering does play a role in French. Both imperative-infinitive and imperative simple expressing generatED occur first, while a gerundive expressing generatING occurs second. In addition, Portuguese showed a strong differentiation between ED-specific and ING-specific forms, and therefore little overlap, but in French, overlap is much greater: only one form, the gerundive, is constrained to one part of the semantic relation (generatING).

English appears the most permissive in terms of both overlap between ED and ING-bearing expressions, and lack of influence of ordering - a combination of the characteristics of the other two languages. While there is a strong preference for infinitive and imperative forms, the influence of the part of the semantic relation only extends, as in French, to a single form: the appearance of the infinitive as an expression of generatED rather than generatING. The influence of ordering appears to be at the level of weak preferences, in line with Portuguese, rather than the stronger role seen in French generation. The distribution of expressions in English generation is shown in figure 3.

Syntax	GeneratED			GeneratING			%
	1st	2nd	Total	1st	2nd	Total	
Infinitive	25	7	32	0	0	0	24.4
Imperative	8	1	9	10	29	39	36.7
Passive	4	3	7	1	0	1	6.1
Nominal	1	1	2	3	20	23	19.0
Other Finite	8	4	12	3	0	3	11.5
Other	0	3	3	0	0	0	2.3

Figure 3: Expressions of Generation: English

Portuguese uses a very small subset of of the available syntactic resources of the language to express **enablement**: only infinitives, imperatives (together, over 85% of the data set) and nominals

⁶We ignore here the singular, familiar imperative.

express enablement⁷. While there was no ordering preference in Portuguese generation, there is an ordering constraint on enablement: imperatives expressing ED do not appear first. The distribution of syntactic forms (figure 4) shows that, while there is a high degree of overlap in terms of expression of ING or ED, a system of preferences operates: the infinitive is three times as likely to be used for the ED than ING component, while the imperative is twice as likely to be used for ING than for ED.

Syntax	EnablED			EnablING			%
	1st	2nd	Total	1st	2nd	Total	
Infinitive	17	8	25	5	3	8	25.4
Imperative	0	29	29	30	19	49	60.0
Nominal	3	2	5	3	2	5	7.7

Figure 4: Expressions of Enablement: Portuguese

French has a relatively broad range of expressions available for enablement (see figure 5)—much wider than Portuguese. As was the case for generation, French enablement shows a strong ordering preference: when an imperative is used as enabled, it must be placed second (if expressing generatED, it must be placed first). The gerundive is strongly marked for generation, and in the rare cases it is used in enablement is restricted to a single semantic role: expressing enablING, rather than enablED—the only French expression so restricted. Enablement is most regularly expressed by the imperative-infinitive.

Syntax	EnablED			EnablING			%
	1st	2nd	Total	1st	2nd	Total	
Imp've-Infin.	6	23	29	27	6	33	47.7
Infinitive	5	13	18	3	3	6	18.5
Gerundive	0	0	0	2	2	4	3.1
Imp've-Simple	0	7	7	10	4	14	16.2
Nominal	5	3	8	5	1	6	10.8

Figure 5: Expressions of Enablement: French

In English (figure 6), although the imperative is the most popular expression of enablement, (over 60% of tokens), when it expresses the enabled part of the relation, it must appear second: to place it first would be misleading, as it would imply that this action should be performed first. There is also a constraint arising from the part of the semantic relation being expressed: infinitives do not express the enablING action. Infinitives are only capable of conveying a goal, and the enablING element is not the goal.

Syntax	EnablED			EnablING			%
	1st	2nd	Total	1st	2nd	Total	
Infinitive	4	4	8	0	0	0	6.1
Imperative	0	31	31	36	13	49	61.5
Passive	0	1	1	3	3	6	5.4
Nominal	9	9	18	3	0	3	16.2
Other Finite Cl.	3	3	6	4	3	7	10.0
Other	1	0	1	0	0	0	0.8

Figure 6: Expressions of Enablement: English

potactic conjunctions.

Discourse		Syntax	
relation	cue	enablED	enablING
Sequence (72.3%)	et (ED) puis (ED) avant de (ED) avant (ED) après (ING) après (ING)	imperative imperative infinitive nominal imperative imperative	imperative imperative imperative imperative infinitive nominal
Purpose (18.5%)	pour (ED) afin de (ED) de façon à (ED)	infinitive, nominal infinitive infinitive	imperative imperative imperative

Figure 10: French: Enablement

The relationship with actual temporal ordering of events plays no role in determining ordering in the case of *avant de* and *après* followed by an infinitive: the two possible orderings are equally likely. In the case of *avant* and *après* followed by a nominal, there is a strong preference for placing the prepositional phrase containing the nominal first. Clearly, this yields an iconic ordering in the case of *après* and a non-iconic ordering in the case of *avant*.

- (5) Après dépoussiérage, appliquer deux couches de peinture vinylique.
After dusting, apply two coats of vinyl paint.
- (6) Avant l'emploi, faites tremper le boyau dans de l'eau tiède.
Before use, soak the tube in warm water.

As in Portuguese, though, both rhetorical relations are clearly marked, and there is a similar, although less marked, tendency to view the semantic content of the enablement relation as being one of temporal sequence.

3.2.3 English

English has the greatest tolerance of unmarked discourse relations among the languages studied: only 37 of the 130 clauses examined appeared with a marker of any kind. The majority of markers were instances of *by* appearing with a nominalisation to convey the generatING part of the relation, showing a preference for communicating this semantic content in terms of the rhetorical relation of MEANS in English⁹ 18 of these 19 instances of *by* appeared when the generatED element was presented first: *by* is used to signal the MEANS relation when confusion might otherwise result from a user attempting to perform the generated action,

⁹As stated at the outset, however, we cannot yet state the ordering of the relevant semantic, syntactic, and rhetorical decisions.

presented first, rather than the generating action.

Discourse		Syntax	
relation	cue	generatED	generatING
Purpose (50.8%)	∅ simply (ING) so that (ED) for (ED)	infinitive infinitive finite clause nominal	{imperative,finite} imperative imperative imperative
Means (29.2%)	by (ING)	{imperative,finite}	nominal
Result (13.8%)	if/when (ING) by (ING) and (ED) ∅	finite subject complement	finite clause nominal imperative nominal
Condition (6.2%)	if (ED)	finite	imperative

Figure 11: English: Generation

The markers *simply* and *just* appear only with generatING imperatives. *For* appears only with NP, and marks only generatED elements. *So that*, which appears rarely, marks only generatED elements. The less common *and*, *if* and *when* could appear with either ING or ED.

Even though English does not mark the two parts of the generation relation explicitly by means of discourse markers, the combination of ordering, syntax, and rhetorical relation results in all but one case in an unambiguous interpretation. PURPOSE, is the only relation that is expressible in both ED-first and ING-first order: in fact, it is only infinitives and *for* with a nominal that can appear either before or after their main clause.¹⁰ The range of rhetorical relations available for the expression of generation is, however, the greatest of the three languages, consisting of a superset of the relations adopted in French and Portuguese.

Enablement in English is expressed most frequently by SEQUENCE, which, with appropriate temporal markers, can appear in both iconic and non-iconic order: the few non-iconic cases (5) are marked with *before*, *follow [ing] by [ed]*, and *followed by*. PURPOSE is also a frequent interpretation. For enablement, some discourse markers are exclusive, and some ambiguous. *If* appears exclusively with the ED-first presentation, and *and*, *then*, *followed by*, *follow X by*, and *now* only appear with the ING-first ordering, as do commas. *To*, *for* and *before* are ambiguous. Finally, *just* and *simply* are markers that only appear with the ING element, but there is always another marker that appears in the ED element in conjunction with them.

¹⁰These alternations in ordering are discussed in (Vander Linden, 1993) in terms of the intention to convey optionality or obligatoriness of the action in the matrix clause.

As was the case with generation in English, there is a high degree of overlap between all other expressions of the two parts of the relation.

3.2 Discourse Markers and Rhetorical Relations

Very strong correlations appear between particular choices of semantic relation and syntactic form on the one hand, and the appearance of discourse markers and/or a strong bias towards a particular rhetorical interpretation on the other. Our analysis shows that selection of syntactic expression and local discourse relation strongly interact, and provides a rather clearer picture of the influences that bear on the mapping from semantics to syntax.

A particularly important element to emerge is the language-specific nature of the choice of rhetorical relation, a notion which we express for the moment in terms of RST-style rhetorical relations, cf. (Mann and Thompson, 1988). The analysis represents a careful but intuitive interpretation of what rhetorical relation would be retrieved, by a native speaker of the language, from the particular combination of syntax, discourse marker, and content. What triggers these interpretations is constrained both by semantic content and by the conventions and syntactic resources available within the languages of study.

3.2.1 Portuguese

Portuguese appears to have *obligatory* signalling of discourse relation by a discourse marker, or at the very least by punctuation⁸. Three discourse relations are available for generation (PURPOSE, CONDITION, RESULT) and two for enablement (PURPOSE, SEQUENCE). For generation, the dominant relation is PURPOSE (80%); for enablement it is SEQUENCE (72%). The overlap in the syntax of generation *vs* enablement sentences is confined to expressions of PURPOSE. Figures 7 and 8 show the relationships between semantic relation and syntax with an overlay of discourse: rhetorical relations and discourse markers.

Discourse		Syntax	
relation	cue	generatED	generatING
Purpose (80.1%)	para ED	infinitive infinitive nominal	{imperative, passive, infinitive} basta + infinitive {imperative, infinitive}
Condition (9.3%)	caso ED se ED	subjunctive + infinitive passive	{basta + infinitive, imperative} infinitive/imperative
Result (1.5%)	e + <i>automaticamente</i> ED	future (agent = artifact)	imperative

Figure 7: Portuguese: Generation

The figures show a strong and unambiguous re-

⁸This can be compared with the finding presented by (Moser and Moore, 1995) in their ACL-95 presentation, that discourse cues are significantly more likely to occur when the 'contributor' component of the relation PRECEDES the 'core' in English dialogues.

lationship between rhetorical relation, discourse marker, and syntax. There is a strong tendency to present generation in terms of the rhetorical relation of PURPOSE, which is marked almost invariably by *para* or *para que* (*so that*), both of which can only take a nominal or infinitival expression. SEQUENCE, on the other hand, is signalled by temporal connectives such as *antes de* (*before*), *depois de* (*after*) or *após* (*after*), by the connective *e* (*and*) or implicitly by the use of a comma between the elements of a string of imperatives. For Portuguese enablement, two relations are preferred: PURPOSE and SEQUENCE, with a strong preference for the latter. Again, the markers of each rhetorical relation are distinct.

Discourse		Syntax	
relation	cue	enablED	enablING
Purpose (18.5%)	para (ED)	{nominal, infinitive} infinitive	imperative basta + infinitive
Sequence (72.3%)	antes de (ED) depois de (ING) após (ING) e (ED)	infinitive imperative imperative imperative	imperative infinitive {nominal, infinitive} imperative imperative

Figure 8: Portuguese: Enablement

3.2.2 French

In French, discourse markers do not accompany all expressions of generation. However, where they do occur, the markers unambiguously assign the expressions to one or other of the plan elements: body (*si*, *en* and *par*) or goal (*pour*, *afin de*, and *de façon à*). While Portuguese generation is overwhelmingly expressed through the rhetorical relation of PURPOSE, in French it is more evenly distributed between PURPOSE and MEANS, with a small showing for CONDITION. Although not shown in the figure, there is only one case in French generation where the choice of ordering of the elements and the choice of marker-plus-expression are not mutually constraining: this is when the preposition *pour* is followed by an infinitive. In this case, the two orderings of the relation (ING first or ED first) are more or less equally probable.

Discourse		Syntax	
relation	cue	generatED	generatING
Purpose (41.5%)	pour ED pour (ED) afin de (ED) de façon à (ED)	infinitive nominal infinitive infinitive	imperative imperative imperative imperative
Condition (0.2%)	si (ING)	finite (future)	finite
Means (43.1%)	en (ING) par (ING)	imperative imperative, finite	gerundive nominal

Figure 9: French: Generation

The expression of enablement in French instructions (figure 10) is limited to two rhetorical relations: SEQUENCE and PURPOSE. Situations where the choice of ordering of the elements and the choice of marker-plus-expression are not mutually constraining are limited to the PURPOSE discourse relation marked by *pour* and the SEQUENCE discourse relation marked otherwise than by hy-

Discourse		Syntax	
relation	cue	enabled	enabling
Sequence (68%)	{and, then, now (ED)} { ϕ , .} {when, after (ING)} follow (ING) by (ED) followed by (ED) before (ED)	imperative finite imperative imperative nominal nominal nominal finite	imperative finite imperative nominal nominal imperative {imperative, finite} finite
Purpose (21.4%)	ϕ for (ED) for (ED) in order to (ED)	infinitive nominal nominal infinitive	{finite,imperative} {finite,imperative} imperative finite
Condition (7.6%)	when (ING) if(ED)	imperative imperative	finite finite
Result (3.0%)	once (ING) which (ED)	finite	finite

Figure 12: English: Enablement

4 Conclusions and Implications

In this paper, we have gone some way towards isolating the *specific* point in the generation procedure at which pragmatic information such as rhetorical relation must be brought into play. Since our notion of semantic content is based on a formal model of the task plan to be conveyed to the instruction user, the significance of the approach is clear for developing natural language generation applications within this limited domain. In particular, for rhetorical planning of the communication of particular content, we can use the preferences observed for selection of the preferred rhetorical relation in the language in question. Second, we can use our knowledge of how that relation is constituted and expressed in terms of syntax for marking the relation appropriately.

The approach also reveals some interesting facts about the individual languages. In particular, we found **different levels of tolerance of residual ambiguity**: Portuguese has little ambiguity in the mapping from semantic content to syntactic realisation (the least ambiguous markers of rhetorical relation, fewest available syntactic realisations, least overlap in the roles of these realisations for conveying one or the other semantic relation, most restricted set of favoured rhetorical relations). English, on the other hand, had the opposite characteristics. We also found differing **preferences for rhetorical relations** in expressing semantic content: for example, while Portuguese expresses generation in over 80% of cases with the relation of PURPOSE, French generation divides this relation almost equally between PURPOSE and MEANS. The English corpus, on the other hand, while it has a strong showing for PURPOSE (around 50%), reveals a relatively strong showing (around 14%) for the relation of RESULT, a relation found in only 1.5% of the Portuguese relations and not at all in French.

No natural language has an unambiguous mapping from semantics to surface syntax, which

makes the information encoded by syntax, both semantic and pragmatic, very difficult to consciously 'unpack' from surface form in the performance of the translation task. We suggest that uncovering the decisions necessary for producing pragmatically-appropriate sets of parallel instructions is a task best performed as an empirical study along the lines suggested here. In this way, we can encode language-specific pragmatic principles into tools that support the process of multilingual document production.

References

- Cecile T. Balkanski. 1993. *Actions, Beliefs and Intentions in Multi-Action Utterances*. Ph.D. thesis, Harvard University, May.
- R. E. Fikes and Nils Nilsson. 1971. STRIPS: a new approach to the application of theorem proving to problem solving. *Artificial Intelligence*, 2:189-208.
- Alvin I. Goldman. 1970. *A Theory of Human Action*. Prentice Hall, Englewood Cliffs, NJ.
- Anthony F. Hartley and Cécile L. Paris. 1995. Supporting Multilingual Document Production: Machine Translation or Multilingual Generation? In *working notes of the IJCAI-95 Workshop on Multilingual Text Generation*, August 20-21, Montréal, Canada. Also available as ITRI report ITRI-95-13.
- William C. Mann and Sandra A. Thompson. 1988. Rhetorical structure theory: Toward a functional theory of text organization. *Text: An Interdisciplinary Journal for the Study of Text*, 8(2):243-281.
- M. Moser and J. Moore. 1995. Investigating Cue Selection and Placement in Tutorial Discourse. In *Proceedings of the 33rd Annual Meeting of the ACL*, pages 130-150, Boston, Mass.
- Cécile Paris, Keith Vander Linden, Markus Fischer, Anthony Hartley, Lyn Pemberton, Richard Power, and Donia Scott. 1995. A support tool for writing multilingual instructions. In *Proceedings of the Fourteenth International Joint Conference on Artificial Intelligence*, August 20-25, Montréal, Canada, pages 1398-1404. Also available as ITRI report ITRI-95-11.
- Martha E. Pollack. 1986. *Inferring Domain Plans in Question-Answering*. SRI Technical Report SRIN-403.
- Earl D. Sacerdoti. 1977. *A Structure for Plans and Behavior*. Elsevier, New York.
- Keith Vander Linden. 1993. *Speaking of Actions: Choosing Rhetorical Status and Grammatical Form in Instructional Text Generation*. Available as Technical Report CU-CS-654-93.