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The Persuasive Tutor: a BDI Teaching Agent with Role and Reference Grammar Language Interface – Sustainable design of a conversational agent for language learning

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Abstract³

This paper investigates how an intelligent teaching agent with Role and Reference Grammar [RRG] (cf. Van Valin 2005) as linguistic engine can support language learning. Based on a user-centred empirical design study the architecture of a highly persuasive tool for language learning as an extension of PLOTLearner (<http://europlot.blogspot.dk/2012/07/try-plotlearner-2.html>) is developed. Based on grounded theory it is shown that feedback and support is of greatest importance even in self-directed computer assisted language learning. It is also shown how this overall approach to language learning can be situated into traditional conversation based learning theories (cf. Laurillard 2009). It is shown that a computationally adequate model of the RRG-linking algorithm, extended into a computational processing model, can account for communication between a learner and the software by employing conceptual graphs to represent mental states in the software agent and the important role of speech acts is emphasized in this context.

1. Introduction

The problems I am working on in this paper are 1) Does a conversational agent for language learning support language learners in their desire to learn a language and how should such an agent look like and 2) How should an architecture for an intelligent teaching agent look like which uses RRG as linguistic engine? Since in this design study I use grounded theory for the analysis of my empirical data no hypothesis is stated. The hypothesis is generated from user-input within a user centred design approach.

Based on qualitative research in terms of a focus group interview and a questionnaire a design study resulting in the architecture for an intelligent teaching agent using RRG (cf. Van Valin and LaPolla 1997; Van Valin 2005) as its linguistic engine is presented. I will introduce the architecture of a highly persuasive learning technology that emulates the presence an artificial tutor as learning supervisor for a learner in a virtual and interactive world. This way artificial intelligence will enable persuasive learner-controlled tutoring for collaborative learning in the community of enquiry. The intelligent teaching agent has a natural language interface using the functional linguistic framework of RRG for both language production and comprehension. This computationally adequate linguistic theory guides the interaction of the learner with the intelligent teaching agent, and this human-computer interaction is structured like an instant messaging system. I will base my work on a user-centred design approach.

3 I would like to thank my family for supporting me during my studies in Denmark. Kim Hülsewede receives my thanks for language correction. Without the support of Erich Herber it would not have been possible to conduct the empirical study, as well as my focus group from Fjellhaug International University College Denmark he deserves my greatest thanks. I would like to thank Hagen Langer for many discussions on intelligent teaching agents. Brian Nolan receives my thanks for many inspiring discussions, his emotional support during the last months and for publishing my paper. Finally I would like to thank my Nicolai Winther-Nielsen for his wonderful supervision, scientific and personal support during the last months. I enjoyed our discussions and am looking forward to many more interesting projects with you.

I am developing the design for persuasive learning in a technology called the PLOTLearner that is being developed in the EU project EuroPLOT (www.eplot.eu). PLOTLearner is a learning environment for database-supported language learning which making it possible to learn Biblical Hebrew with the ancient language of the Hebrew Bible, which is stored in an Emdros database. The learning environment generates database-informed grammatical exercises. PLOTLearner turns the Hebrew Bible into a pedagogical tutor. Through interactive and pedagogical expose to the Hebrew texts, the learner is gradually guided into learning Hebrew and studying the culture (cf. Winther-Nielsen 2012: 1).

In the course of the development of the BDI teaching agent, I will use a lexicalist approach to RRG, which is crucially informed by an architecture of the mental lexicon as developed in Gottschalk (2010, 2012). I will use an extension of the RRG-linking algorithm based on Gottschalk's (2012) approach to a computationally adequate model of RRG. My version of a computational adequate RRG uses conceptual graphs [CGs] for the representation of the semantic structure of sentences that are processed by the teaching agent.

This paper is organized as follows in section 2 the concept of my user-centred design is laid out and presented within a taxonomical framework for classifying design approaches based on Keinonen (2009). Qualitative data gathering and a focus group interview is the topic of section 3 in which I describe in detail my empirical data gathering and data analysis. In section 4 the basic theory of RRG is introduced. The concept of intelligent software agents is introduced in section 5 and section six contains the architecture of an RRG-driven teaching agent and the different phases within the workflow of this architecture is described. A conclusion is contained in section 7.

2. Design approach

Human-centred design is an area of research which has received much attention during the last couple of years (cf. Keinonen 2009). User-centred design is defined by generative research. In this approach, design generatively evolves during a design approach that is informed by user interaction (cf. Sanders 2005: 2). Keinonen (2009) has introduced a design contribution square that makes it possible to taxonomically classify the degree to which users are involved in such a generative design approach. This is illustrated in figure 1. In inactiveness, behaviour is not influenced by design. It is not easy to be documented and communication is usually unambiguous. If the design behaviour is reactive, it is also possible that communication is unambiguous; however, an effective and replicable design process can be found. Participants in design studies respond to new stimuli. This is true for designers as well as for users or co-creators. In a proactive design approach, all participants react to new stimuli; however they also reframe problems and agendas of design. Also, participants utilize non-task related expertise (cf. Keinonen 2009: 145).

In cases where well-structured methods or rules are employed for guiding the design interaction, designers and users are in a reactive mode. This method has dominated human-centred design. It is called traditional user-centred design. In this design

approach, design is conducted on behalf of the user; however a user constantly informs it. Keinonen (2009: 146) describes this design approach as follows:

For instance, a usability test [47] aiming at evaluating the quality of a prototype or product – rather than improving it – with its predefined task scenarios, measurements and participant roles is an example of an interaction with agenda that ties both users and designers. The interaction can lead to increased understanding about known challenges like the quality of design in the interactive prototype, but is unlikely to reveal anything completely unexpected. Collaborative design sessions aiming at new solutions following predefined rules and problem frames belong also to this category. Even though many human centered design scholars would probably argue for changing these situations towards a more proactive direction, there are reasons to accept the participants' relative passivity. First, evaluation processes benefit from following rigid agendas for comparable results. Second, problems with collaboration and communication may be time consuming to solve, and thus agendas structuring design and focusing attention to relevant problems bring practical efficiency benefits. Consequently, the method development challenge for *DreUre* type of HCD is to develop interaction agendas that are able to structure, focus and standardize collaborative procedures in a way that still accommodates many of the relevant aspects of design (Keinonen 2009: 146f).

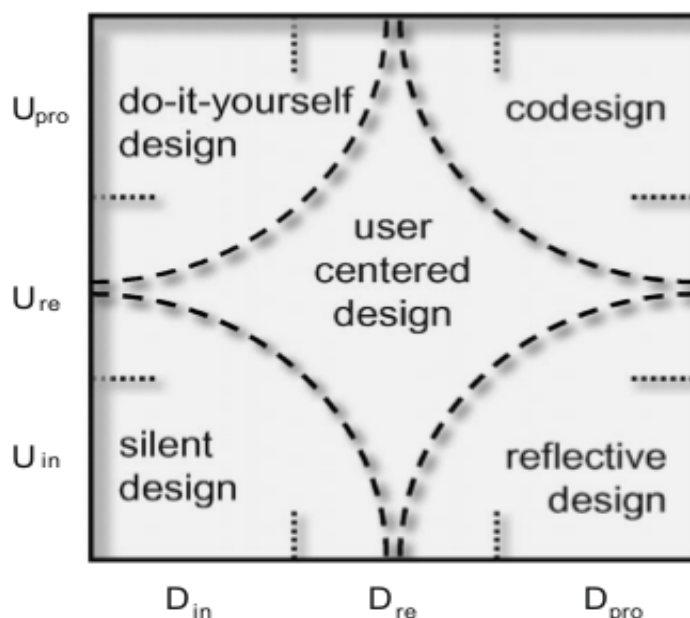


Figure 1: Human centred design approaches positioned on Design Contribution Square

(U_{pro}: proactive user contribution, U_{re}: reactive user contribution, U_{in}: inactive user contributions, D_{pro}: proactive designer contribution, D_{re}: reactive designer contribution, D_{in}: inactive designer contribution) (Keinonen 2009: 146)

The present design study had to face the problem that I, as designer, am situated in Düsseldorf, Germany, while my users are situated in Copenhagen, Denmark. Given this specific situation, cut backs in the designer's involvement as well the involvement of users had to be made. My design study was mainly informed by traditional research methods, like focus group interviews and questionnaires (cf. Hanington 2003: 13). These methods provided an efficient means to reach my users in Copenhagen.

The design study followed structured methods or rules in that I chose qualitative data gathering as basis for the development of a first prototype of the persuasive tutor. In

a first step, the concept for the persuasive tutor was developed on the basis of brainstorming and mind maps, which I used for the creation of an idea for the improvement of the PLOTLearner in its current state. The design question that guided this first step was in how far natural language processing can be used in order to improve language learning within the PLOTLearner. Based on this initial step in the design study, I have roughly sketched a first idea of an RRG-driven intelligent software agent and then I have interviewed my focus group in Copenhagen. This focus group interview was supported by a qualitative questionnaire, in which the users had the possibility to express their opinion about a persuasive tutor in more detail. Based on this user input, it was possible to have a clear picture of what the users expect from such a persuasive tutor and it was possible to revise my design approach.

This design approach was interactive in the sense that two data gathering methods were chosen, and that the design was generated from user input. In that sense, a generative research approach was conducted. The communication with the user was unambiguous in any situation, as well as the users' responses. Since the design approach followed a clear schema, with focus groups interviews after a prototype was developed, as well as the use of an initial questionnaire, the approach was replicable. This is also true for the behaviour of the users in that they constantly participated in these design steps. With new prototypes and accordingly new focus group interviews, I responded to the new stimuli of the user, who also responded to the new stimuli in terms of a new prototype in focus group interviews. Given this design approach my design study can, based on Keinonen's (2009) taxonomy, be classified as user-centred design.

In the next section I will introduce my qualitative data gathering process and my analysis based on grounded theory will be roughly sketched.

3. Empirical data gathering, data processing and coding

The reactive interaction with the focus group in Copenhagen was conducted in two steps. It consisted of a focus group interview and a qualitative questionnaire. I chose grounded theory to evaluate the user responses to both my qualitative data gathering in terms of the questionnaire and the focus group interview. Grounded theory is an approach to analysing qualitative data and to developing a scientific theory from the systematic analysis and interpretation of empirical data (cf. Rogers et al. 2011: 297). This approach was first developed by Glaser and Strauss (1967). The approach chosen in grounded theory is to develop a theory that fits to the data collected. A grounded scientific theory is developed by alternating data collection and the analysis of this data (cf. Rogers et al. 2011: 297). In a first step data is collected via qualitative questionnaires or focus group interviews and then categories within the data are identified. In a second step, further data collection is conducted and interactively analysed. This interaction takes place until a proper theory is developed (cf. Rogers et al. 2011: 297). This way, new insights to a specific topic are gathered.

Following Rogers et al. (2011: 297) the following coding steps are executed in order to develop the theory: 1) open coding, which is the process which leads to the first categories with properties and dimensions which are informed by the data 2) axial

coding, which is the process which leads to a systematic fleshing out of categories which are set into relation to their subcategories 3) selected coding, a step in which categories are organized around a central category which forms the theory's backbone (cf. Rogers et al. 2011: 297).

The focus group consisted of four informants. The informants are all currently enrolled in the bachelor program in theology at Fjellhaug International University College Denmark and are all male. They are between 20 and 25 years old and participate in a class on Biblical Hebrew with a weekly workload of 24 hours. The learning format chosen is corpus-driven self-directed persuasive language learning. The teacher functions as facilitator. The learners are taught the text of the Hebrew Bible. The teacher gives feedback to the learners in oral discussions in class as well as in e-mails as response to learning statistics the learners send to him on a regular basis. Sending the learning statistics to the teacher is voluntary, as he keeps the promise of letting the learners do their class work self-directed and independently. This has the result that he does not always get the statistics from the learners. In class, the students watch learning videos and use learning sheets with corresponding information on the Hebrew grammar. To support their grammatical drills, the learners use PLOTLearner.

The in the focus group interview I asked the following: *Imagine PLOTLearner had an interactive help function that starts to communicate with you once it recognizes that you get stuck in your exercises. Please give some opinion on this.* They were asked to argue for their specific opinion and to discuss this question controversially. Only little guidance from the interviewer was provided. In the second step of my data gathering process, I conducted an online survey, in which I used a qualitative questionnaire in order to ask the learners more detailed questions about the envisioned teaching agent.

In a first step of the data analysis, a line-by-line analysis based on the answers given in the focus group interview and the questionnaire was conducted. I identified diverse categories derived from the data. In the course of this coding step, I identified key words in the data and brought them into a larger context, which summarizes the answers of the informants. Two examples for the open coding tables are given in tables 1 and 2 below. All other tables are to be found in appendix A.

Table 1: Open Coding

<i>Imagine the learning software could give you advice via text messages when you get stuck with an exercise. Would you like that? Give reasons!</i>	
Answer	Sample codes generated and notes
It would be a great help, especially if there are links to more knowledge.	1. Desire for <u>support</u> 2. <u>Knowledge building</u> through links to more knowledge
Absolutely, that will be great, because it removes unnecessary waste of time and frustration in the learning process	1. Reduction of frustration through timely and efficient support. 2. <u>Encouragement</u> through reduction of frustration
It would be helpful. To solve learning problems immediately is good.	1. <u>Support</u> in learning through immediate feedback. 2. <u>Efficiency</u> through immediate feedback

Table 2: Open Coding

<i>Imagine you are supervised by the learning software via textual dialogues. What feedback would you like to have from the learning software? - Give examples!</i>	
Answer	Sample codes generated and notes
Suggestions to where I need to improve. Information about what my most common mistake is.	1. <u>Knowledge building</u> through suggestions for improvement. 2. Display of most common mistake for <u>efficient</u> learning.
Not answered	
Just short and specific grammatical advice.	1. <u>Knowledge building</u> through advice. 2. <u>Efficiency</u> through short and succinct advance

From the initial open coding, the following categories which play a role in the development of an persuasive intelligent tutoring system which extends PLOTLearner can be derived: Feedback, Support, Collaboration, Communication, Efficiency, Knowledge building, role change, competition and competition.

From the global categories, it is possible to derive axial coding in terms of a hierarchical model that describes the interactions of the different elements at play in the envisioned extension of PLOTLearner with an RRG-driven BDI teaching agent. This diagram is given in figure 2 below:

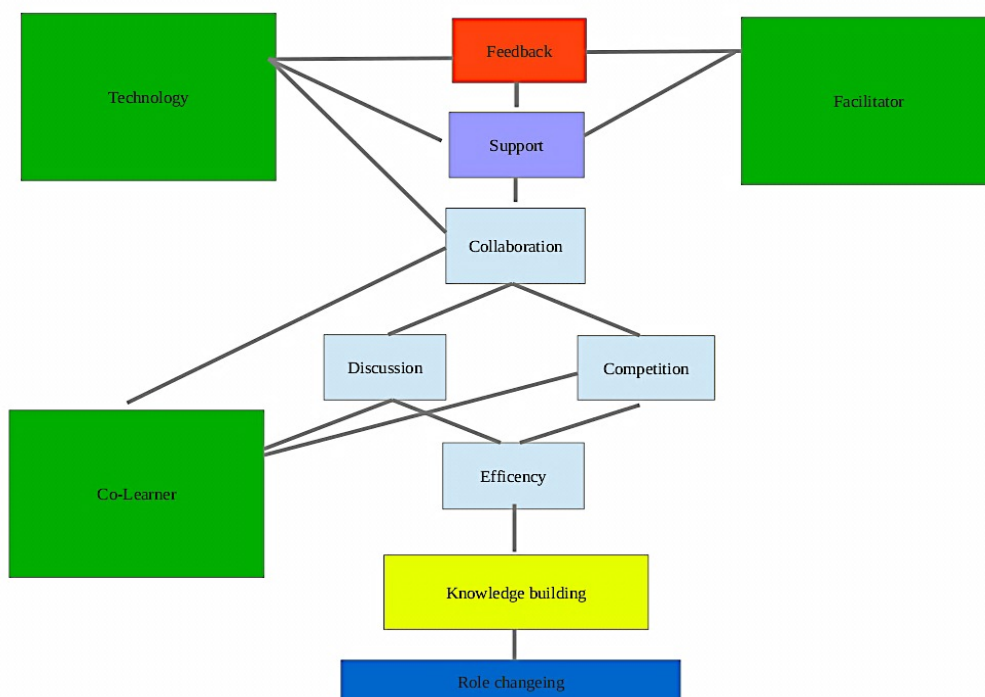


Figure 2: Axial coding and hierarchical model of empirical data

From the open coding, it was possible to identify the need for feedback as a core issue for successful learning and as a desire of the learners. An interview with the facilitator of the focus group in Copenhagen, Nicolai Winther-Nielsen, has shown that for the learners feedback in class is important for their learning process. As the open coding suggests, the feedback directly results in support with problems that occur in the learning process. Collaboration plays a part in learning with PLOTLearner. The reason for this is that the learners are self-directed learners in a university environment in which the facilitator is their main source for support and feedback.

However, as pointed out in the focus group interview, in a context in which the facilitator is unavailable and the envisioned teaching agent can not give the desired support and feedback, collaboration is desired. In these situations the learners can collaborate with other learners via discussions and competition. Collaboration should always be efficient. Efficiency plays a very important role in all kinds of interaction the learners could have. They have a desire to get short and succinct help with problems in their learning progress and, as pointed out by the learners in the focus group interview, this need also results in a degree of collaboration, supported by the fact that the learners would only like to collaborate with learners who have already mastered a problem, rather than mastering a problem with the learning object in collaboration with other learners.

These different steps lead, as shown in figure 2, to the aim of the self-directed learning process: Knowledge building. If the learning object is mastered, the learners also would like to change their roles. In this situation, the learners are willing to act as facilitators and to support other learners. This actually results in a learning circle, in which self-directed learning applies and which PLOTLearner supports with its extension by an intelligent tutoring system. These findings lead me to an overall theory, in which feedback is the backbone, supported by self-directed learning with PLOTLearner. In these situations, as in learning at home, the teaching agent supports the learners with short and succinct answers on specific problems with the learning object. The agent is used in situations where the facilitator is not available. This way, the important role of efficiency is underpinned. It also gives feedback on the learning process, which should help the learners' master the learning object. In situations where the teaching agent cannot give the desired support and feedback, it leaves room for collaboration with other learners who have already mastered the problem, and directs learners to such advanced co-learners. The teaching agent supports discussion and gives the possibility for competition on the learning object. A further function of this collaboration dimension of the teaching agent is to give the possibility for role changing to further support collaboration in PLOTLearner.

This theoretical approach is supported by theoretical findings developed in Laurillard (2009). In her approach to conversational learning theory, Laurillard (2009) uses an approach that is driven by social interaction between learners and the facilitator (cf. Conole et al. 2004: 20). In this model, the role of interpersonal relationships, which involve imitation and modelling, is emphasized (cf. Conole et al. 2004: 20). In this framework, language is used as a tool for learning as well as for the construction of knowledge. Following Laurillard, language in this framework has two functions: First it is a communicative or cultural tool, used for sharing and for jointly developing knowledge. However language is also a psychological tool, used for the organization

of individual thoughts for reasoning, planning and reviewing of the learner's actions (cf. Conole et al. 2004).

This pedagogical framework can clearly be found in PLOTLearner as a tool for self-directed learning in which the learner communicates with the learning object via quizzes; however it is also found in the learning context in which the focus group at Fjellhaug International University College Denmark learns Hebrew and uses PLOTLearner, as the direct contact between the facilitator in class supports the use of language as a communicative tool.

However, in her approach to conversational learning theory Laurillard (2009) also emphasizes the role of communication between learners in a collaborative context, in which the learning object is mastered in a communicative concept, in which the learners reflect about the learning object. In an approach to PLOTLearner which uses the fact that the learners would like to use communication and feedback from the learning software as well as their facilitator and their peers, Laurillard's (2009) pedagogical framework is of major importance.

Nevertheless, the learning conception realized by PLOTLearner is also bound to a second pedagogical framework, which can be subsumed under the heading 'Constructivism'. Constructivism focuses on processes that cause knowledge building in the learners and giving them the possibility to build their own mental structures when they interact with their environment (cf. Conole et al. 2004: 19). The pedagogical focus in this learning model is task-oriented and it favors hands-on, self-directed activities that are oriented towards design and discovery. This approach is useful for structured learning in things like simulated worlds and it supports the construction of conceptual structures through the engagement in self-directed tasks (cf. Conole et al. 2004: 19).

While the conversational framework as described by Laurillard (2009) would especially apply to the envisioned extension of PLOTLearner with the intelligent teaching agent in that it constantly gives feedback and support to the learners, constructivism is already realized in PLOTLearner through its self-directed learning approach, which is also realized in the learning environment at Fjellhaug International University College Denmark. This clearly shows that in a teaching approach in which a teaching agent is used, a well-established learning framework can be realized.

In the next section, I will present in some detail the computational linguistics approach to RRG as it is laid out in Gottschalk (2012) and which, although also developed to some detail, is still a work in progress.

4. Role and Reference Grammar

RRG is a monostratal functionalist theory. It uses a single syntactic description which is semantically motivated and does not assume abstract underlying levels of syntactic representations as they are used in Government and Binding Theory and Relational grammar (cf. Van Valin 1991: 154; cf. Van Valin 2005: 1). RRG employs a semantic representation based on Aktionsarten as they are developed by Vendler (1969) and Dowty (1979). For this correspondence, RRG uses a linking algorithm,

which directly links the semantic representation of the clause with its syntactic representation (cf. Van Valin 2005). Based on this, RRG is both a lexicalist and a functionalist theory (cf. Van Valin 1991: 154). Also, RRG uses a representation of information structure to account for the communicative function of the utterance (cf. Van Valin 2005: 1).

In what follows I will give a general overview of RRG, in which I will describe the basic theory of RRG as developed in Van Valin (2005) and Gottschalk (2012). The focus here is clearly on the computational adequate model of RRG as presented in Gottschalk (2012).

Word order regularities in RRG are described in terms of the layered structure of the clause [LSC], which displays clause structure. Phrases in the LSC are semantically motivated and contain components every human language has (cf. Van Valin 2005: 4). The underlying semantic units from which the syntactic units are projected in the LSC are summarized in table 3.

Table 3: Semantic units underlying the syntactic units of the LSC (Van Valin 2005: 5)

Semantic element(s)	Syntactic unit
Predicate	Nucleus
Argument in semantic representation of predicate	Core argument
Non-arguments	Periphery:
Predicate + Arguments	Core
Predicate + Arguments + Non-arguments	Clause (= Core + Periphery)

As pointed out in Van Valin (2005: 8), although the LSC is semantically motivated, all units are syntactic. Beside the semantic units given in table 3, RRG also assumes additional syntactic elements that can occur in single-clause sentences. The precore slot [PrCS] is one of these elements. It is the position in which question words occur in languages in which they do not occur *in situ*. Also, the PrCS is the place where fronted elements occur, as in the sentence: *Unjustice, Batman doesn't like* (cf. Van Valin 2005: 5).

Not all languages have a PrCS, but in languages that do have it Van Valin (2005: 8) proposes that it is pragmatically motivated. As shown in figure 3, the PrCS is inside the clause but it is not part of the core (cf. Diedrichsen 2008: 204).

As shown in figure 3, the question word *what* occurs in the PrCS. This is typical for languages like English, since here the question word does not occur *in situ* (cf. Van Valin 2005: 5). The verb *say* is the nucleus. The nucleus is the heart of both the semantic and the syntactic representation of the clause. The reference phrase *Batman* is a direct core argument while *to Alfred* is an oblique core argument. The reason for this is that it has an oblique case and is marked by a preposition. The PP *in Wayne Manor* and the adverb *yesterday* form the periphery which modifies the core (cf. Van Valin 2005: 7). Van Valin (2005: 13) explains that the LSC is stored in terms of syntactic templates in the syntactic inventory. With the help of the linking algorithm, parts of syntactic templates are matched to create a full LSC. As noted in Van Valin and LaPolla (1997: 69f), syntactic templates are formally equivalent to ID/LP-rules, which were found in unification grammar like GPSG. This fact will be of crucial importance for the development of an RRG-based parser.

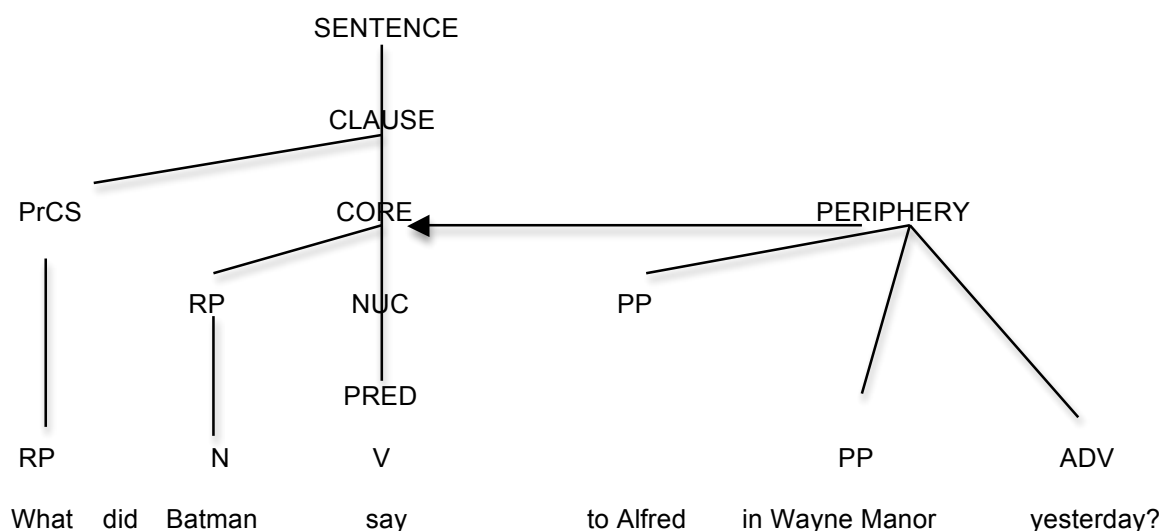


Figure 3: Layered structure of the clause

In RRG a semantic representation of clauses is used based on the Aktionsart classification adapted from Vendler (1969) (cf. Van Valin 2005: 31). In this classification, sentences are divided into states, achievements, accomplishments and activities (cf. Gottschalk 2010: 21). In order to construct logical structures from which the LSC is projected, RRG employs an extended representation of Dowty's (1979) semantic representations of Aktionsarten (cf. Van Valin 2005: 31). Besides the Aktionsarten used in Vendler's framework, RRG also uses a number of non-Vendlerian Aktionsarten. The added Aktionsarten are Semelfactives, Active Accomplishments and Process. Semelfactives have been added in Smith (1997). Gottschalk (2010) shows that the Aktionsart Process also exists. All Aktionsarten have a causative counterpart in RRG. With causatives the semantic differences are described in which a cause, for example a change in condition, can be identified (cf. Gottschalk 2010: 21). In RRG, Aktionsarten are defined by binary features (1).

(1) (Gottschalk 2010: 21)

State:	[+ static], [- dynamic], [- telic], [- punctual]
Activity:	[- static], [+ dynamic], [- telic], [- punctual]
Achievement:	[- static], [± dynamic], [+ telic], [+ punctual]
Semelfactive:	[- static], [± dynamic], [- telic], [+ punctual]
Process:	[- static], [- dynamic], [- telic], [- punctual]
Accomplishment:	[- static], [- dynamic], [+ telic], [- punctual]
Active Accomplishment:	[- static], [+ dynamic], [+ telic], [- punctual]

RRG uses several syntactic and semantic tests to determine the Aktionsart of a verb. The formal semantic representations of Aktionsarten in RRG are called logical structures [LSs]. An overview of them is given in (2).

Semantic roles play an important role in RRG. In Van Valin's (2005) approach to RRG the semantic macroroles actor and undergoer are used. However in Gottschalk (2012) it was shown that these semantic macroroles are epiphenomenal and therefore a number of lexical semantic relations was introduced, which are stored in inheritance networks in the mental lexicon. These lexical semantic relations are

stored within attribute value matrices in the mental lexicon and a unification-based inheritance process assigns them. This is described in length in Gottschalk (2012).

(2) (Gottschalk 2010: 22)

State	predicate' (x) or (x, y)
Activity	do' (x, [predicate' (x) or (x, y)])
Achievement	INGR predicate' (x) or (x, y) or INGR do' (x, [predicate' (x) or (x, y)])
Semelfactive	SEML predicate' (x) or (x, y) or SEML do' (x, [predicate' (x) or (x, y)])
Process	PROC predicate' (x) or (x, y)
Accomplishment	PROC predicate' (x, (y)) & INGR predicate' ((z), y)
Active Accomplishment	do' (x, [predicate' (x, (y))]) & INGR predicate' ((z), y)
Causative	α CAUSE β where α, β , are LSs of any type

In a new approach to the semantic representation of Aktionsarten in RRG, I will propose the use of CGs instead of the traditional semantic representation as proposed in Van Valin (2005). The reason for this is that, as shown in Petersen (2007), it is possible to automatically generate CGs from an input text. This is highly desirable for a computational approach to RRG.

The linking algorithm is bi-directional in the sense that it links the semantic representation with the syntactic representation and vice versa. This linking system makes it possible that, based on a procedural set of instructions, as in a programming language like C or C++, the semantic representation can be generated from the syntactic representation and vice versa.

From a computational linguistics perspective, RRG makes seriously strong claims about being a computational adequate linguistic theory in the sense of being executable on a computational device. One reason for this is in virtue of the application of a generalized linking system in terms of the linking algorithm as developed in Van Valin (2005: 136). In Gottschalk (2012) it was shown that RRG is not computational adequate in the sense of not being executable on a theoretical machine model like a random access machine. Therefore, the RRG linking algorithm was adjusted on a theoretical basis to develop a computationally tractable model of RRG. RRG's architecture which consists of a bidirectional linking algorithm triggers the idea that this algorithm could be used as the communicative basis for a talking computational device which finally led to research on intelligent software agents that could be used in a collaborative learning environment and the aim to develop a persuasive and intelligent tutoring system using RRG as its linguistic engine. In this paper it was shown that much reliance on the mental lexicon and on constructional schemas is necessary. The new version of the linking algorithm can be found in Gottschalk (2012) where it is discussed in detail.

5. BDI teaching agents

The theoretical foundation I use for the teaching agent is based on a model of human behaviour developed by philosophers to model human behaviour. The name of this model is the **belief, intention, desire** model and the philosophical basis of this model has been developed by Bratman (1987) (cf. Bordini, Hübner and Wooldridge 2007: 15).

In this conception of a BDI agent it is assumed that the computer has mental states. Beliefs in this context are defined as what the agent knows about the world (cf. Bordnini, Wooldridge and Hübner 2007: 15). In the case on the teaching environment what the agent knows about the world is the status of the learning progress of the agent according to which it acts. Desires are all the states of affairs that the agent possibly might like to accomplish. That the agent does have a desire does not mean however that the agent acts according to it. Rather a desire is a potential influencer for an action. One can also interpret a desire as an option (cf. Bordnini, Hübner and Wooldridge 2007: 16). Intentions play an important role in practical reasoning. What is most important with respect to intentions is that they lead to action (cf. Wooldridge 2002: 28). Once an intention is adopted the fact of having this intention constraints the future practical reasoning. While some particular intention is held, options will be entertained which are consistent with this intention (cf. Wooldridge 2002: 29). Intentions are closely related to beliefs about the future. This means if an agent has an intention it should believe in this intention. This means if an agent does not truly believe in its intention then it would make no sense to have this intention. Intentions have a number of different roles within practical reasoning. Intentions play a role in driving means-end reason; once an intention arises, the agent will attempt to achieve this intention. This involves the decision of how to achieve the intention and if the achievement of an intention fails another way of achieving it needs to be developed (cf. Wooldridge 2002: 29).

For the implementation of this approach a possible account is to use a control loop in which the agent looks at the world, in the case of PLOTLearner this is the learning environment, and deliberates to decide on which action it should achieve. In the case of the agent these are communicative and they are supported by speech acts. I will refer to this in this section 6. The agent uses means-ends reasoning to develop a plan to achieve this intention. The agent chooses a possible communicative strategy, in this case a speech act and based on this executes its plan, which in a conversational agent is a communication (cf. Bordnini, Hübner and Wooldridge 2007: 20).

Now that I have introduced the conception of a BDI agent I will focus on the architecture of an RRG driven agent in the next section and will show how the concepts of beliefs, intentions and desires can be realized within an RRG context.

6. Reference architecture for an intelligent teaching agent

The envisioned rough architecture of an extension of PLOTLearner and which contains an intelligent tutoring system is made up of two intelligent software agents. This is due to the fact that in this approach I have chosen a modular architecture in which different tasks in this framework are distributed over a number of agents. This is illustrated in figure 4.

In this framework, PLOTLearner interacts with a statistical database connected with a supervisor agent. This agent supervises the learning success of the learner based on statistical data which is send from PLOTLearner to the database. The supervisor agent supervises the learning statistics of the learner that are stored in the database. Once this agent recognizes that a learner gets stuck in her learning due to, for

example, making many mistakes or due to a very long response time, the supervisor agent calls the conversational agent, which starts a communication with the learner. The conversational agent is connected with an Emdros knowledge base, which contains knowledge on grammatical questions and which can be manually populated by the users of PLOTLearner. In this paper I focus on the architecture of the conversational agent and how RRG can be implemented within such a computational framework. Therefore, in figure 5 the architecture of the conversational framework as practical implementation of RRG is given.

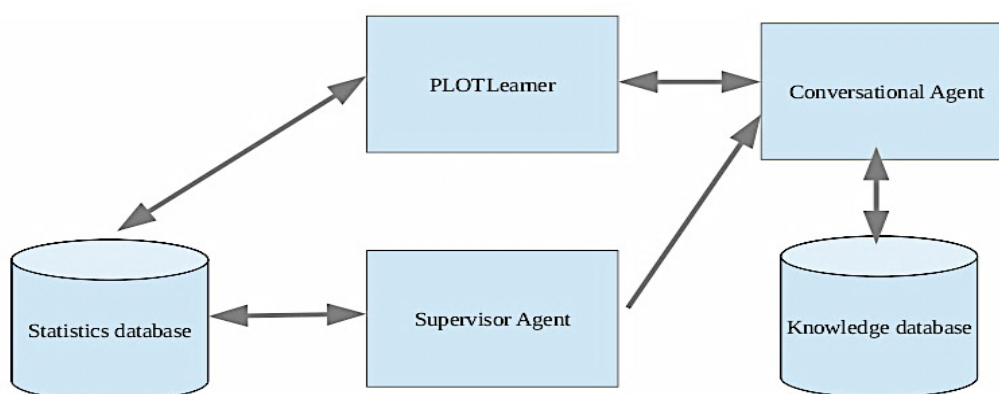


Figure 4: Rough architecture of BDI-agent based extension of PLOTLearner

The architecture of the parse and generation process for the conversational agent given in this figure describes a flow of a number of bi-directional processes which starts with an input sentence typed in by a learner and ends with an output sentence generated by the sentence generator. It is organized in a number of phases which are laid out in detail in what follows: The phases described in the following are crucially influenced by an approach presented in Murtagh (2011).

Phase 1 Processing

In the first phase, an English sentence is input by the user. It is stored as string. Based on an approach in Murtagh (2011: 98) with regard to RRG the sentence is classified as State, Activity, Achievement or Accomplishment. After this took place the sentence is tokenized. Each token is a word and it is stored in terms of a suitable data structure. The tokens are searched in the lexicon in terms of an attribute value matrix [AVM] and based on this information the relevant grammatical information is assigned. As pointed out in Murtagh (2011: 98) the information must be stored with the lexical item in a specified data structure. The result of this step is that for all tokens there will be a better sense of the word order of the string (cf. Murtagh 2011: 98).

Phase 2 – Parsing

In phase 2 the tokenized and annotated tokens are parsed and an RRG-based syntax tree in terms of a data structure is generated. As pointed out in Van Valin and LaPolla (1997: 69ff) syntactic templates as used in Van Valin and LaPolla (1997) and Van Valin (2005) are formally equivalent to an ID/LP-syntax as found in GPSG. This allows the use of an ID/LP-parser in which an extended version of an Earley

algorithm applies. This parsing method for RRG is similar to an approach which is described in Guest (2008) and in Wilson (2009). In both approaches to RRG-parsing the syntactic templates used by Van Valin are broken down to simple ID/LP rules for the corresponding language and stored as data structure in the construction repository. Once the algorithm applied the ID/LP-rules can be used and a syntax tree is generated.

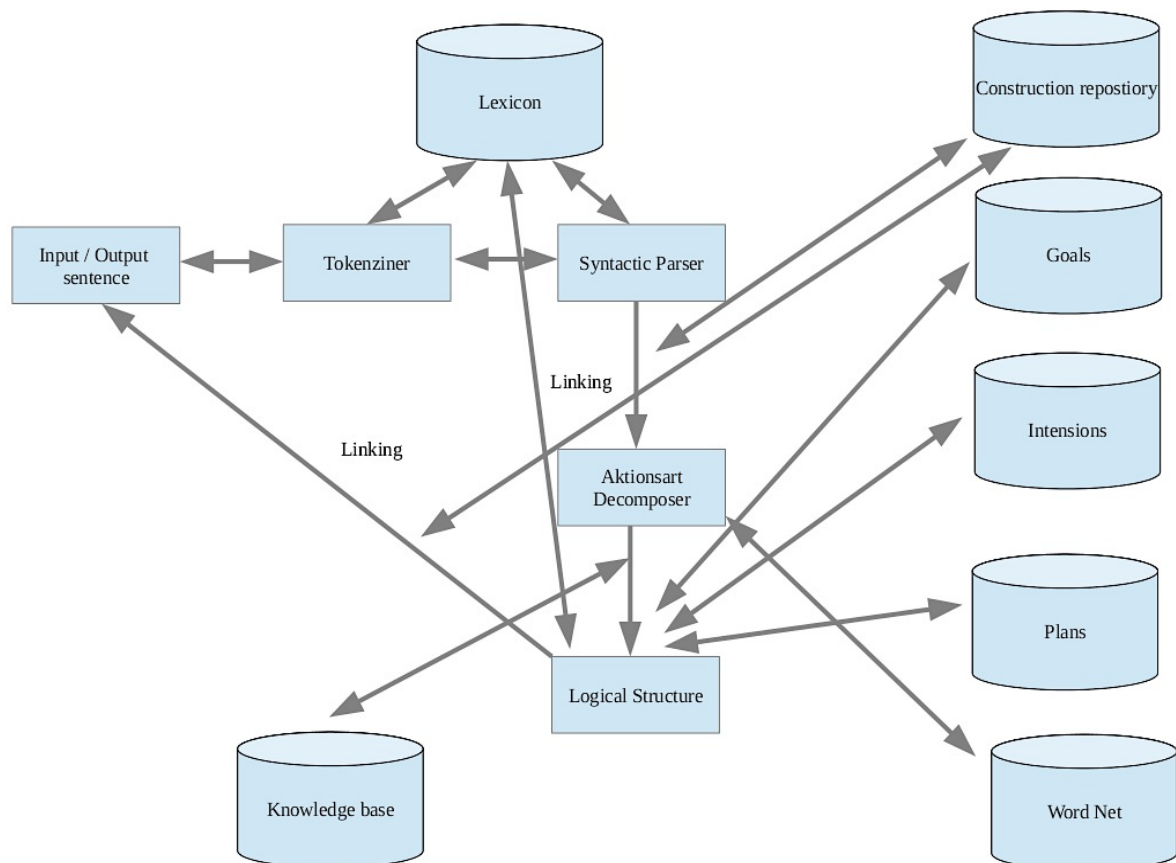


Figure 5: Architecture of the language module

Phase 3 – Linking algorithm

In phase 3 the linking algorithm is executed. For this a revised version of the linking algorithm developed in Van Valin (2005) will be used which is informed by a computational process for the generation of conceptual graphs developed in Petersen (2007). The approach here is that the ID/LP-informed trees generated in phase 2 are decomposed as conceptual graph.

The linking algorithm is actually extended to a computational processing model of RRG as initially suggested in Gottschalk (2012). Here the linking algorithm is part of what Bordini, Hübner and Wooldridge (2007: 20f) call a control loop in which the belief, desire and intention database of the teaching agent is constantly updated. In the case where the linking algorithm is activated the agent is called by the user herself and, by her question, the beliefs are updated. This way, the CG needed for language production in phase 4 is updated by a formal representation of updated

beliefs represented in the CG metalanguage. Also in this phase initial intentions that the agent has are updated in the sense of the activation of the intention to support the learner in her learning progress. In order to update intentions speech acts are used which are formally stored in the lexicon.

This idea is based on work of Austin (1962) and Searle (1969). Here speech act theory starts from the principle that language is action and that an utterance either in terms of language, or in this case in terms of extra-linguistic statistical information, is an attempt to change the world. These speech acts are used to motivate the agent to have the intention to change the world. Desires in this context are different options the agent has in order to act according to the intentions it has derived from speech acts. Speech acts in this framework are stored in terms of a limited number of hard-wired AVMs in the lexicon. Inheritance networks in the mental lexicon as well as a Wordnet-based ontology are used to be able to derive speech acts from input sentences.

If the conversational agent is called by the supervisor agent beliefs, intentions and desires are called by the statistical information derived. The conceptual graph necessary for further communication with the agent is generated by a function that can derive information from the statistical database into CGs.

Phase 4 – Semantics to Syntax linking

This step applies when the agent responds to a request from the user or when the supervisor agent has called the conversational agent. In both situations the response by the agent is informed by a CG activated in phase 3. In a first step the logical structure in form of a CG is generated and is informed by information from the beliefs, desires and intentions which have been updated in phase 3. Here the agent has used information from speech acts stored in the lexicon and generated from the input CG in phase 3. In the course of the execution of this linking algorithm the different linking steps as outlined in Gottschalk (2012) will be executed and the output sentence projected from a CG generated in response to information the agent received in phase 3.

For the generation of such a CG not only lexical information plays an important role but also discourse pragmatics applies. For this discourse representation structures in terms of AVMs as well as speech acts are used. In order to properly generate a response to the user, the Emdros database that contains information on the learning object is called. The agent this way generates its response from different sources: the beliefs, intention and desires updated in phase 3, the lexicon which it needs for the necessary vocabulary and the knowledge from the Emdros knowledge base. How this is formally and technically done is a topic for future research.

Further, this step is informed by the construction repository since, as shown in Gottschalk (2012), constructional schemas, which are like objects in a programming language and activate when the standard linking algorithm cannot apply, are needed in this step.

7. Conclusion

Based on an empirical study and its analysis with grounded theory it was possible to identify the need for feedback and support even in self-directed learners as a driving force in their learning progress and to see that there is a great need for a teaching agent which serves these desires. It was possible to show that RRG, as a functional linguistic theory, can be used as the linguistic engine for a BDI teaching agent as the RRG linking algorithm naturally fits into the conception of natural language processing. The empirical study helped to develop an architecture for a teaching agent in which communication is used for effective learning with PLOTLearner. This pedagogical approach was crucially informed by conversation theory as developed in Laurillard (2009).

The architecture of the teaching agent shows how far a descriptive linguistic theory like RRG can be translated into a computational processing model. A first starting point for this is the inclusion of speech acts to the standard theory of RRG and which can result in a computational device that actually talks.

This paper is the starting point for broad research on the development of RRG-driven teaching software and many topics like the development of a CG-based approach to the semantic representation in RRG are still under development. It will be a task for future research to formally include speech acts to RRG and to develop an ID/LP-parser for parsing in RRG.

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Appendix of sample responses

<i>Imagine the learning software could give you advice via text messages when you get stuck with an exercise would you like that - Give reasons!</i>	
Answer	Sample codes generated and notes
It would be a great help. Specially if there is links to more knowledge.	<ol style="list-style-type: none"> 1. Desire for support. 2. <u>Knowledge building</u> through links to more knowledge
Absolutely, that will be great, because it removes unnecessary waste of time and frustration in the learning process	<ol style="list-style-type: none"> 1. Reduction of frustration through timely and <u>efficient</u> support. 2. <u>Encouragement</u> through reduction of frustration
I would be helpful. To solve learning problems immediately is good.	<ol style="list-style-type: none"> 1. <u>Support</u> in leaning through immediate feedback. 2. <u>Efficiency</u> through immediate feedback

<i>Imagine you are supervised by the learning software via textual dialogues. What feedback would you like to have from the learning software - Give examples!</i>	
Answer	Sample codes generated and notes
Suggestions to where i need to improve. Information about what my most common mistakes is.	<ol style="list-style-type: none"> 1. <u>Knowledge building</u> through suggestions for improvement. 2. Display of most common mistake for <u>efficient</u> learning.
Not answered	
Just short and specific grammatical advice.	<ol style="list-style-type: none"> 1. <u>Knowledge building</u> through advice. 2. <u>Efficiency</u> through short and succinct advice.

<i>Imagine the learning software could negotiate learning outcomes with you before you do your exercises via a text messaging system and could give you feedback on how well you did on your exercises after your learning session is done, would that improve your learning progress?</i>	
Answer	Sample codes generated and notes
I think it would be an improvement to have a more direct feedback...then I can work on the problems.	<ol style="list-style-type: none"> 1. Desire for <u>support</u> through <u>feedback</u>. 2. Through <u>efficient</u> <u>feedback</u> opportunity to solve problems. 3. <u>Knowledge building</u> through <u>feedback</u>
I don't think so	<ol style="list-style-type: none"> 1. Improvement of learning through <u>feedback</u>
It's kind of hypothetical, and hard to imagine, but I think it would be beneficially.	<ol style="list-style-type: none"> 1. Improvement of learning process through <u>feedback</u>

<i>Would you like to cooperate with other learners in doing your exercises?</i>	
Answer	Sample codes generated and notes
We could compete and help each other	<ol style="list-style-type: none"> 1. Knowledge building and <u>improvement</u> of learning through <u>competition</u>. 2. Desire for <u>cooperation</u> through competition and <u>supporting each other</u>.
Discuss some topics on grammar could be helpful.	<ol style="list-style-type: none"> 1. Knowledge building through <u>collaborative discussion</u> and <u>communication</u>. 2. Efficient talking about grammatical questions to this way gaining knowledge in <u>specific areas</u>.
I work best in my own speed and level.	<ol style="list-style-type: none"> 1. Desire for self-directed learning and <u>independence</u>

<i>Imagine you get stuck and the learning software could direct you to other learners who already mastered this exercises would you like to have a cooperation - Give reasons?</i>	
Answer	Sample codes generated and notes
I think it would be a good idea.	<ol style="list-style-type: none"> 1. Desire for <u>collaboration</u> through <u>communication</u>.
Sure, if that was possible	<ol style="list-style-type: none"> 1. Desire for <u>collaboration</u> through <u>communication</u>.
The system or a student... I don't care, as long as I get help.	<ol style="list-style-type: none"> 1. Desire for <u>efficient support</u>. 2. Wish for getting <u>feedback</u>.

<i>Imagine PLOTlearner had an interactive help function which starts to communicate with you once it recognizes that you get stuck. Please state an advice.</i>	
Answer	Sample codes generated and notes
I think it would be very helpful if the system gave me feedback but I am not sure whether I would like to interact with other users.	<ol style="list-style-type: none"> 1. Desire for getting feedback. 2. Due to <u>self-directed learning</u> <u>limited desire for collaboration</u>.
Yes, it would be an advantage if I had the possibility to be supervised by the system but the question is whether it would help me to interact with other users.	<ol style="list-style-type: none"> 1. Advantage of being supervised through the system and getting feedback through interaction. 2. Questions interaction with users. Maybe <u>doubts whether the feedback is qualified</u>.