Logical interpretation of omission in implicature

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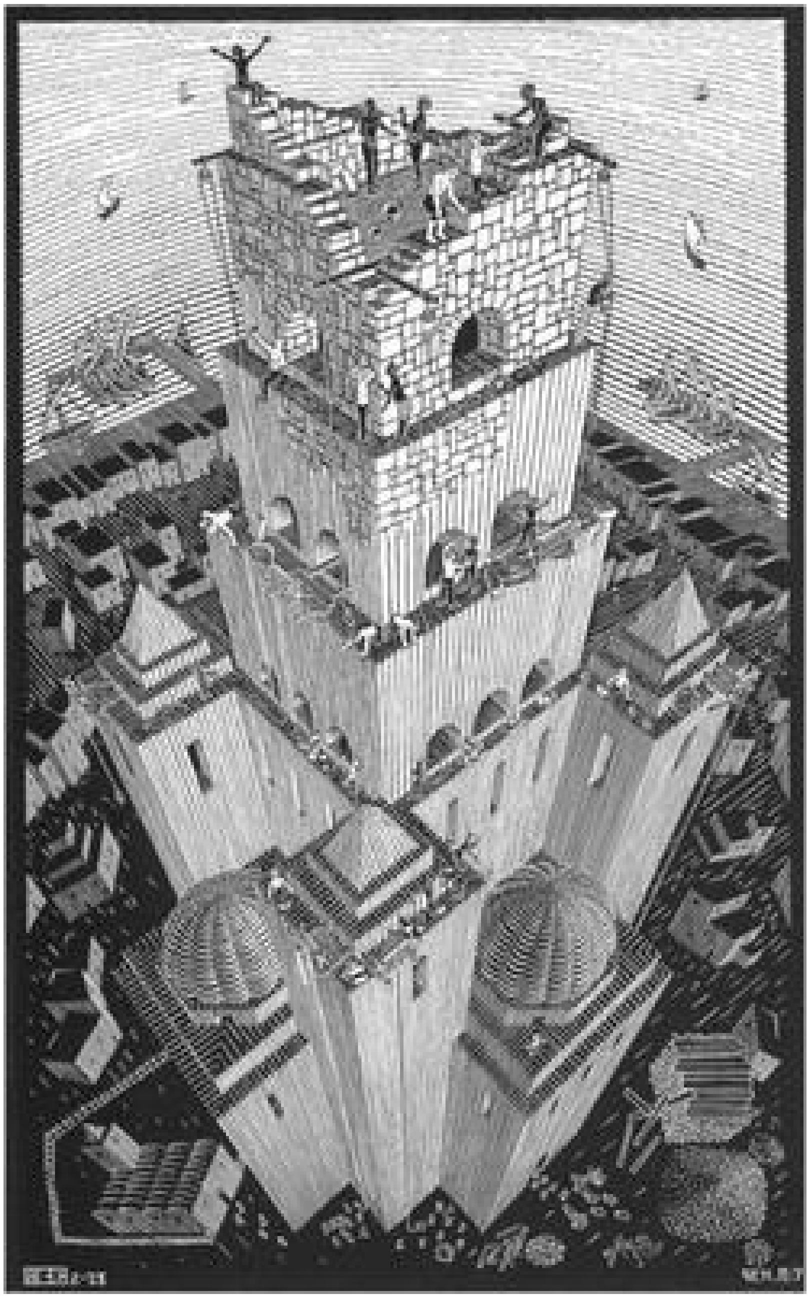
Abstract

Implicatures allow us to make inferences from what is said, and can be conversational or conventional, both of linguistic nature. We can also make inferences from the omission, when presented as intentional silence in a conversation. Without silence and voice, effective communication is impossible because nobody would be listening.

Here, we propose to formulate the logical interpretation of intentional silence as implicature in conversations and testimonies, to make informed decisions, using knowledge representation, and defining a semantics, developing models and implementing them. The area of conversational implicatures can directly benefit from these economies to scale up the phenomena that can be implemented inside a real-time dialogue system, with mutual information and intelligent interactions. The results of this work could have an impact on the disciplines related to artificial intelligence such as man-machine interface, natural language processing, communication between agents, intelligent systems, games theory, applications for mobile phones and social networks, among others.



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1 Introduction

As part of the relations that we establish in a day to day basis, we make inferences that originate from conversation. We can say that these acts are a natural consequence of the interaction among people and have a direct impact on the acquisition of knowledge and its updating. In several cases, such inferences are a natural implication known as implicature, under the assumption of the Cooperative Principle (CP). This consists of the participants making their conversational contribution, as required in the scenario in which this occurs, for the accepted purpose or direction of the speech exchange in which they are engaged. The implicature can be conversational or conventional.

The conversational implicature is a potential inference that is not a logical implication and is related to the word "says" [16], adhering to the CP through the categories that contain the maxims of Grice, which are:

1. Quantity. Make your informative contribution as required for current exchange purposes. Do not make more informative contributions than required.
2. Quality. Do not say what you think is false. Do not say that for which you lack adequate evidence.
3. Relation. Be relevant.
4. Manner. This category is related to the way something is said and includes the supermaxim 'Be perspicuous' and various maxims such as:
    - Avoid obscurity of expression.
    - Avoid ambiguity.
    - Be brief (avoid unnecessary prolixity).
    - Be orderly.

In the following dialogue, we have an example of a conversational implicature:

A: Want a cup of coffee?

B: I just took one

Although different ways of expressing the same propositional content of B were looked for, the most certain fact is that all of them would give the same result:

a. I just had a cup

b. A moment ago I had a cup

c. I just drank a cup

In this example, the normal act is to infer that B does not want a cup of coffee.

Conventional implicature is related with some words that appear in expressions, for example, in the sentence: "John lives in México but is happy" the only thing that is considered "said" is that "John lives in Mexico and is happy." The word "but" is irrelevant for what was said, and evokes what was "not said". From it, we can infer a variety of possibilities, for example:

a. John did not believe to be happy in México

b. Other persons did not believe that he can be happy in México.

c. Are not happy people who live in México?

Both conversational and conventional implicatures are linguistic inferences [11].

A particular case of linguistic inference is that achieved when a response is omitted in the form of intentional silence and the answer is perceived as such. For example, let return to the example of conversational implicature. What would A have inferred if B had intentionally omitted his answer? Some possibilities are:

a) Yes

b) No

c) You do not know, so:

   i) The question must be repeated immediately.
   ii) The question must be repeated at another time.
   iii) Forget about the question.

The interpretation of omission will always depend on context. For example, if A and B have previously drank coffee together, the silence is consent and A infers "Yes". If B considers that he must protect himself, and set a distance due to factors such as sex, religion, politics or social status (social distance [4], [2]) that does not allow him to accept the cup of coffee with A, the omission of B could be interpreted by A as "No". These two possibilities are identified as polarity by Kurzon [20].

Finally, when the context is not favorable so that A can interpret the omission of B as "Yes" or "No", he would not know what to do and could resort to repeat the question immediately, later or never.

It is important to tackle the problem of the interpretation of the omission of one of the participants in an interaction, because in some contexts, inferences or tacit acts can be achieved without breaking the communication. Tacit acts are actions that we do not explicitly mention, but manage to convey anyway, when we say something [3] or when we omit something. The area of conversational implicatures can directly benefit from these economies to scale up the phenomena that can be implemented inside a real-time dialogue system, with mutual information and intelligent interactions [3]. So, the study of the implicature, considering social norms ([10]), can have an impact in some areas of Artificial Intelligence such as Man-Machine Interfaces, Multi-Agent Systems, and Robotics, as well as in the application of Logic in Law.

1.1 Motivation

The omission or intentional silence as part of the communicative process is embedded in a context and has not been sufficiently studied by researchers. Two reasons for this are offered by Dyne, Ang and Botero [8]:

First, many view silence as the absence of speech (essentially a non-behaviour). When speech does not occur, the absence of behaviour is not particularly obvious and does not attract attention. Second, and related to this first point, the absence of behaviour is more difficult to study than more overt and more obvious behaviour.

Traditional conceptualizations of silence emphasize relatively passive behaviour. All forms of silence, however, do not represent passive behaviour, and silence is not merely the opposite of voice [29].

The communication literature emphasizes positive aspects of silence, viewing it as a critical component of social interaction [19]. For example, Scott [29] described silence and speech as two dialectical components of effective communication. Without both silence and voice, effective communication is impossible because no one would be listening.

The conditions for accessing, producing, receiving and participating in discourse are not afforded randomly, but interact with social status, resulting in spaces of meaning ratification where specific forms conventionally receive specific functions [28]. Silence and absence are at the heart of the process of construction of meanings as an act of suppression and is necessary to look at such a process [1].

In interactions, we must think the omissions embedded in the context of the participants, otherwise they are meaningless. That is to say, the context and placing of stretches of silence need to be understood as resources for interpretation for the interactants themselves, and need to be analysed as such [28].

For Grice [16], silence breaks the Cooperative Principle (CP) in category 4 (Manner), at this point, the difference between omission and unintentional silence has to be done since silence, when is intentional, generates implicatures where the CP is not necessarily broken.

According to the previous reasons, we consider important the study of the omission or intentional silence to reach implicatures. The problem is relevant because the study of the interpretation of omission during the interaction, from the computational point of view, could have an impact on disciplines related to artificial intelligence: man-machine interfaces, natural language processing, communication between agents, intelligent systems, applications for mobile phones and social networks, among other.

1.2 Justification

Implicatures have to include also the omission, which must be interpreted in its context, allowing inferences and the continuity of the Cooperative Principle. The silence has been studied by several disciplines but barely touched in logic or artificial intelligence.

For some time, formal dialogue games have been applied in various contexts in computer science and artificial intelligence, particularly as the basis for interaction between autonomous software agents [22]. The formal study of dialogues is relatively new and proposing a semantics of the omission or intentional silence, for complementing communication, is important in decision making.

Other area of application, where the interpretation of the omission of an answer is important, is in the analysis of testimonies, i.e. when someone decides not to testify in a trial or to the corresponding authorities, that is, decide voluntarily or by someone's request, not to cooperate and remain silent [20].

When the silence is intentional then is active, concise, purposeful, powerful and completely brief.

1.3 Frame and assessment

Silence has been studied in different disciplines, such as anthropology, literature, communication, linguistic, philosophy and pragmatics among others. In this proposal we will study the omission or intentional silence in implicatures from the point of view of computer science.

Fig. 1 shows some important references related to the concepts of implication and omission, as well as some references of computational sciences necessary for the development of solutions. The intersection of the three areas represents our area of interest.

We will use abductive reasoning by selecting a set of logical-linguistic puzzles with the following tasks:

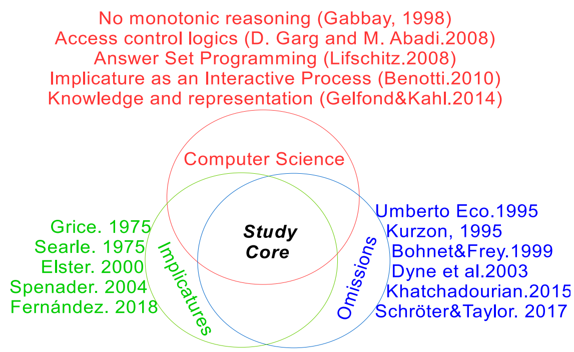

Figure 1. Area of interest.

1. Formalization of statements.
2. Programming the solution of the original puzzle.
3. Application of defined omissions (predictions).
4. Generation of the corresponding models.
5. Logical comparison of the predictions with the original solution.

We consider the Choose proof technique for testimony cases and GIVE (Generating Instructions in Virtual Environments) challenge [5] as a possible instrument for evaluating of dialogue cases.

In addition, given the novelty of theme, the models and the proposed theory will be validated in different scenarios or case studies and subject to scrutiny in diverse forums organized by the scientific community.

1.4 Specific problems to address

Due to the multidisciplinarity of the research in question, we intend to address the overall issue according to the following specific problems:

1. Elaboration of a typology and classification of silence. It is important to have a classification of silence from the point of view of computer science to complement the communicative process.
2. Set the theoretical basis for the consideration of intentional silence. Define the omission in implicatures to arrive to the semantics of intentional silence.
3. Explore models in different contexts. With application of logic and the silence semantics in testimonies and dialogues, generate models for decisions making.
4. Application of concepts in practical cases. That is, identify actual problems to apply the defined theory.

2 Theoretical basis

This section we discuss some concepts related to the computational discipline, useful for our research.

2.1 Logic

Classical logic is a reference for many other logics since some are its extensions or other replaces the axiom of negation. For example, the Deontic Logic is an extension that uses operators for its three principles (distribution, permission and contingency) focused on the management of social norms. The system of Deontic Logic studies propositions (and truth-functions of propositions) about the obligatory, permitted, forbidden, and other (derivative) deontic characters of acts (and performance-functions of acts) [37].

Intuitionistic Logic, denoted by I, is based on the concept of proof rather than truth [15], and is a Positive Logic (Pos) with the additional axioms Int1 and Int2 for the handling of negation. These axioms are:

Pos1. $a \to (b \to a)$
Pos2. $(a \to (b \to c)) \to ((a \to b) \to (a \to c))$
Pos3. $a \wedge b \to a$
Pos4. $a \wedge b \to b$
Pos5. $a \to (b \to (a \wedge b))$
Pos6. $a \to (a \vee b)$
Pos7. $b \to (a \vee b)$
Pos8. $(a \to c) \to ((b \to c) \to ((a \vee b) \to c))$
Int1. $(a \to b) \to ((a \to \neg b) \to \neg a)$
Int2. $\neg a \to (a \to b)$

With Pos1 and Pos2 and the inference rule Modus Ponens is possible to prove the Theorem of Deduction. An interpretation M is said to be a model for a set Γ of well-formed formulas (wffs) if and only if every wff in Γ is true for M [24].

2.2 Logic programming

A *clause* is a formula of the form $H \leftarrow B$ where H and B are arbitrary formulas in principle, called head and body of the clause respectively. There are several types of clauses. If $H = \{\}$ the clause is called a constraint and we can write that clause as $\leftarrow B$. Analogously, if $B = \{\}$ then the clause is called a fact and can be written as $H \leftarrow$. An augmented clause is a clause where H and B are some conjunction, disjunction or denial [14]. Hp and Bp contain positive atoms. Hn and Bn contain negative atoms.

A *logic program* is then a finite set of clauses. If all the clauses in a program are of a certain type, we say that the program is also of that type. For example, a set of augmented clauses specifies an augmented program, a set of free clauses is a free program and so is in the case of the disjunctive and definite programs [14].

A $\wedge \vee \neg formula$ is a formula built only with the logical connectors: $\wedge, \vee$ and $\neg$ arbitrarily used and properly nested.

Figure 2 shows the classification of types of clauses that can lead to the corresponding logic programs.

According to Gelfond [14], so far we have used our knowledge bases to get information about the truth or falsity of some statements or to find objects satisfying some simple properties. These types of tasks are normally performed by database systems. Even though the language's ability to express recursive definitions and the methodology of representing defaults and various forms of incomplete information gave us additional power and allowed us to construct rich and elaboration-tolerant knowledge bases, the types of queries essentially remained the same as in databases.

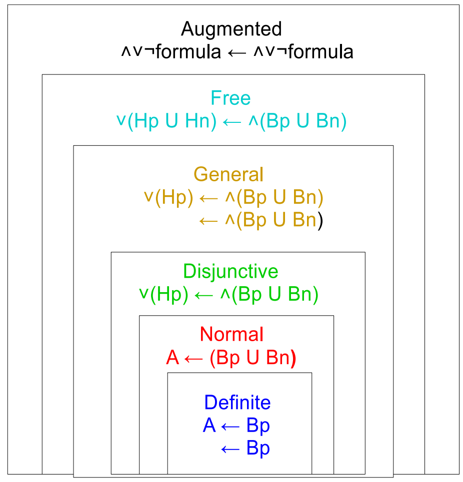

Figure 2. Types of clauses.

Significantly different computational problems can be reduced to finding answer sets of logic programs. The method of solving computational problems by reducing them to finding the answer sets of logic programs is often called the answer-set programming (ASP) paradigm. It has been used for finding solutions to a variety of programming tasks, ranging from building decision support systems for the Space Shuttle and computer system configuration to solving problems arising in bio-informatics, zoology, and linguistics. Moreover, there is a theorem by Pearce [26] where he characterizes ASP in terms of intuitionistic logic and vice versa.

There are currently several ASP inference engines called ASP solvers capable of computing answer sets of programs with millions of ground rules, for example, Smodels and Dlv since 2002, Clasp and Clingo since 2007, of the Potsdam Answer Set Solving Collection (POTASSCO).

2.3 Argumentation and graphs

A useful tool for the elaboration of diagrams, knowledge representation and interactions is graph theory. In particular, graphs have been used for the specification of arguments, an important element in law and the study of testimonies [38].

For example, Dung's seminal abstract framework consists of a set of arguments and one type of interaction between them, namely the attack relation. What really means is the way arguments are in conflict [6]. A Dung's argumentation framework (AF, for short) is a pair $< A, R >$, where A is a finite and non-empty set of arguments and R is a binary relation over A (a subset of A x A), called the attack relation. An argumentation framework can be represented by a directed graph, called the interaction graph, in which the nodes represent arguments and the edges are defined by the attack relation: $a, b \in A$, aRb is represented by $a \nrightarrow b$.

Definition (Extensions). Given $< A, R >$ and $S \subseteq A$:

- S is a preferred extension of $< A, R >$ *iff* it is a maximal (with respect to $\subseteq$) admissible set.

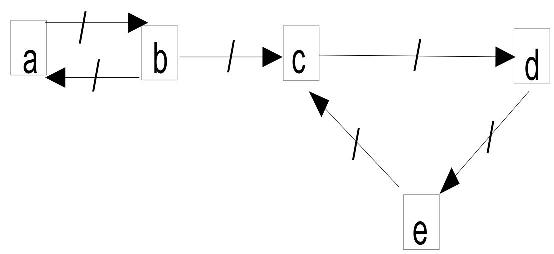

Figure 3. Graph of argumentation.

- S is a stable extension of $< A, R >$ *iff* it is conflict-free and for each $a \in S$, there is $b \in S$ such that bRa.
- S is the grounded extension of $< A, R >$ *iff* it is the least (with respect to $\subseteq$) admissible set X such that each argument acceptable with respect to X belongs to X.

Example. Let AF be defined by A = {a, b, c, d, e} and $R_{att} = \{(a,b),(b,a),(b,c),(c,d),(d,e),(e,c)\}$, represented by the graph of Fig. 3. There are two preferred extensions ($\{a\}$ and $\{b,d\}$), one stable extension ($\{b,d\}$) and the grounded extension is the empty set.

2.4 BDI Model

Belief, Desire, Intention (BDI) model is an architecture for a rational agent having certain *mental attitudes* [27]. The BDI model is a computational model for the problem of determining, given a utterance, which speech act has to be accomplished. BDI model as whole can be represented by the following components:

1. Belief: The knowledge of the world, i.e. the state of the world for the agent.
2. Desire: The objective to accomplish, i.e. the desired end state.
3. Intention: The course of actions currently under execution to achieve the desire of the agent.
4. A set of plans supplied at design stage.

In Fig. 4 we can observe the execution cycle of the BDI model [18].

Rational agents need plans for two reasons. First of all, agents need to "allow deliberation and rational reflection to influence action beyond the present", since agents have only limited resources (including time) to deliberate at the time of action. Secondly agents need to coordinate their actions, both on an intrapersonal and a interpersonal level, and plans help agents with that, too [25].

An example where Cooperative Principle of Grice can be expressed as a desire and shared plan is proposed by Grosz and Sidner [17]:

```
CDRI:
     MB(Gl, G2, Desire(G1, P) &
```

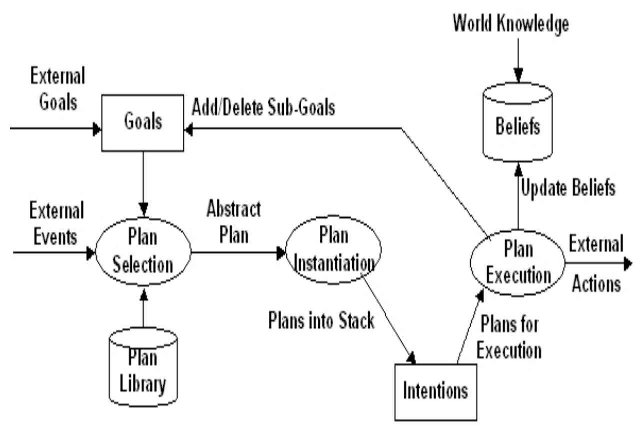

Figure 4. BDI model.

```
Cooperative(G1, G2) &
Communicating(G1, G2, Desire(G1, P))) =>
MB(G1, G2, Desire(G1, Achieve(SharedPlan(G1, G2, Achieve(P)))))
```

A first approximation to this rule is that if the participants believe that one of them, say G1, has a particular desire, for instance to achieve a state in which P holds, and they are cooperative (in general, and with respect to achieving states like P in particular), and if they are communicating about the desire to achieve P, then they mutually believe that G1 has a desire for them to construct a shared plan to achieve P.

A disadvantage of the BDI model is that determining the speech act associated to a utterance is a problem quite complex since many (or even most) sentences do not seem to have the speech act associated from their syntactic form [3].

3 Related work

Here we highlight some formal definitions of both implicature and omission considering some concepts included in the introduction. Since everybody recurs to omission or silence, the number of possible interpretations is large, but some thinkers have tried to capture the silence meaning and have shared their ideas.

Silence can be found in architecture, philosophy, music, literature and a wide range of knowledge areas.

The implicature can be conversational, conventional or omissive. In this section, we discuss some concepts related to the implicature and omission required for the research proposal.

3.1 Implicature

Grice [16] introduces the important concepts for the development of this work, such as the conversational implicature through the cooperative principle and the maxims.

For example in the dialogue:
A: I am out of petrol.
B: There is a garage around the corner.
B conversationally implicates: the garage is open and has petrol to sell.

In Stanford Encyclopedia of Philosophy [40], we have the following formal definition of implicature:
A representative formulation goes as follows, with S the speaker and H the hearer (also referred as addressee).

Definition 3.1. *Implicature* is formally defined as: S conversationally implicates p iff S implicates p when:

(i) S is presumed to be observing the Cooperative Principle (cooperative presumption);

(ii) The supposition that S believes p is required to make $S's$ utterance consistent with the Cooperative Principle (determinacy); and

(iii) S believes (or knows), and expects H to believe that S believes, that H is able to determine that (ii) is true (mutual knowledge).

The implicatures arise from speech acts. In Searle [30], we have three parts of a speech act:

1. Locutionary act.- Communicative act.
2. Illocutionary act.- Speakers intention.
3. Perlocutionary act.- The effect that speech act has on the context participants world.

Spenader in [34] holds that sentences types have conventional relationships to certain types of speech acts:

1. Declarative (assertions): *The class finishes at 6 p. m.*
2. Interrogative (questions): *Does this class finish at 6 p. m.?*
3. Imperative (orders): *Stop teaching inmediately!*
4. Optative (wishes): *I wish this class would be over!*

Benotti [3] shows the use that conversational implicatures have in an interactive process, as part of the communication, and proposes Frolog software as a dialogue game for context maintenance. She also mentions the importance the concept of tacit act or implicit.

According to Ruiz [11], for Grice, the conventional implicature refers to certain linguistic phenomena with the following characteristics:

a) Contents are implied
b) They originate in non-truthful meaning of certain words and phrases
c) These do not influence the truth value of the statement in which they originate
d) They can not be canceled

e) These are separable

f) Such phenomena originate in the systemic (conventional) meaning of the expression

g) They are not analyzable pragmatically but semantically

Examples of these contents are the words: *but*, *therefore*, *so* and *moreover*. Ruiz [11] holds that conventional implicature is related with generating expressions that contain such words.

3.2 Omission

In Scott [29], we found that the silence and speech are two dialectical components of effective communication. Without both silence and voice, effective communication is impossible because no one would be listening.

According to the Kurzon model [20], in the event that a witness or an accused is interrogated, the possible response includes parameters of presence and non-presence. The presence can include speech and non-presence the silence, as shown in Fig. 5. There are two types of silence, intentional and unintentional. Intentional silence is a deliberate action not to cooperate with the other party and unintentional silence is psychological in nature.

Intentional silence manners or modal interpretations:

1. I may not tell you
2. I must not tell you
3. I shall not tell you
4. I will not tell you

Manners 1 and 2 are intentional external silences “by order”. Manners 3 and 4 are intentional internal silences “by will”.

In conclusion, we can say that there are three possible modal interpretations of silence:

- Unintentional: “I cannot speak”.
- Intentional:
  - Internal (willingness): “I will/shall not speak”
  - External: “I must/may not speak”

The one left remaining “I need not speak” is apparently internal, in that the source of the silence is the addressee himself or herself.

The interpretation of silence must be contextual. For example, in a normal conversation, in court, silence is interpreted to the detriment of the person who is silent. The immediate reaction is that she hides something. The intentional silence is also a sign of group loyalty.

The silence is defined by language and points to three types of silence [21]:

- Psychological silence. The help of a decoder is necessary.

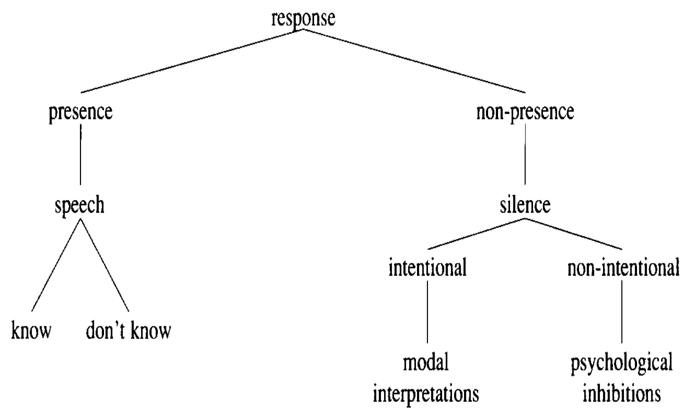

Figure 5. Kurzon model.

- Interactive silence. It occurs as an intentional pause in the conversation allowing the other person to draw inferences related to the meaning of the conversation.
- Socio-cultural silence. When silence is interpreted based on specific cultural codes.

For Bohnet [4], the variants for the interpretation of silence can be: anonymous and not anonymous, the latter can be with identification and face-to-face.

According to Dyne, Ang and Botero [8], an intentional silence is:

1. Defensive. Where this silence is proactive, involving awareness and consideration of alternatives, followed by a conscious decision to withhold ideas, information, and opinions as the best personal strategy at the moment.
2. Acquiescent. This silence suggests disengaged behaviour that is more passive than active. In this case, who remains silent agrees implicitly with what others say.
3. ProSocial. This silence is proactive and other-oriented, based on altruism and cooperation.

Acording to Schröter and Taylor [28], deliberate silence can include: concealment, censorship, omission, evasion, lying, deception, or metalinguistic comments, other aspects of silence that are also open for exploration.

For Umberto Eco [9], the silence can be intentional or nonintentional, has an emitter and a receptor whose intention must be explicit. From the point of view of semiotics, intentional silence is a sign.

In a communication scheme that includes the interpretation of silence in its basic form, the speaker has to interpret the silence that the listener sends with a certain intention. The sender becomes the receiver of silence.

According to Eco [9], a communication process in which there is no code, and therefore in which there is no meaning, is reduced to a stimulus-response process. The stimuli do not conform to one of the most elementary definitions of the sign, which states that "it is put in place of something else". The stimulus is not put in place of something else, but "directly provokes" this other thing. A dazzling light that forces me to close my eyes is a different thing from a verbal command that forces me to close my eyes. In the first case, I close my eyes without thinking; in the second, first of all I have to understand the order and decode the message (sign process) and then decide if I obey. The study of signs and their functioning is called semiotics or semiology. Semiotics has three main areas:

1. The sign itself. This is the study of different types of signs, of their way of carrying meanings and of relating to those who use them, because signs are human creations, and can only be understood in terms of how people use them.

2. The codes or systems of organization of signs. Here we study how a variety of codes have been developed to meet the needs of a society or a culture, or to exploit the communication channels available for transmission.

3. The culture within which these codes and signs operate. This, in turn, depends for its own existence and form, on the use of these codes and signs.

The three ways to consider the sign are:

- Semantics. The sign is considered in relation to what it means.

- Syntactic. The sign is considered as susceptible to being inserted in sequences of other signs, according to some combinatorial rules.

- Pragmatic. The sign is considered in relation to its own origins, the effects on its recipients or for example, the use they make of them. This third dimension is the darkest.

3.3 Omissions in dialogue

Omissions that generate inferences during everyday dialogues are common, however, there are situations where such omissions are even more significant. Below is one of these examples with some key signs or transcription keys.

In the dialogue below, the use of *no comment* by suspects in police interviews [28], the officer (OF) goes further in attempting to obtain some response from the suspect (SUS), moving the suspect from resistance to participation, making it clear that the suspect is aware of the potential repercussions of remaining silent. During the dialogue some transcription keys are used, additional keys can be used in other dialogues, but those in the example are detailed at the end.

Interview

1. OF: Anything else?

2. OF2: (hhhh) the inevitable question but where did you get the stuff from?

3. SUS: No comment

4. (5.9)

5. OF: Okay so an overall round up

Transcription Keys

1. (number) pauses of over a number of seconds.

2. (h) exhalation with the number of 'h's indicating length of breath.

There is a representative sample in [12] of this kind of dialogues with expressions (i.e., *no comment*) that generate conventional implicatures. This opens another line to work later on since is another phenomenon close to intentional silence or omission.

3.3.1 Dialogue games

Game theory has had a high impact in various areas such as economics, through optimization with operation research. When interactions and utterances are involved, the applications enter the field of language and open possibilities for their analysis, such is the case of text-adventures games and dialogue games. Text-adventures games are computer programs that simulate a physical environment. The player manipulates the game world using natural language requests. The game replies describing the game world and the results of the players actions. An example the this type of game is Frolog [3].

The study of formal dialogue games consists of [23]:

1. Rule-governed interactions between two or more players (or agents).

2. Each player moves by making utterances.

Among the tools to achieve the interaction between agents are protocols, programming languages, and the semantics associated. For the case of dialogue games, some of these tools are:

- Languages and protocols for agent communications:

  - KQML (Knowledge Query and Manipulation Language).

  - ACL (Agent Communications Languages of Foundation for Intelligent Physical Agents).

  - Fatio (Five locutions added to the 22 of FIPA):
    illocution(p_i, ϕ) means that speaker p_i asserts a statement ϕ.

    1. assert(p_i, ϕ).
    2. question(p_j, p_i, ϕ).
    3. challenge(p_j, p_i, ϕ).
    4. justify(p_i, $\Phi \vdash^{+} \phi$).
    5. retract(p_i, ϕ).

- Semantics:

- Axiomatic. This can be public or private, and contains Pre-conditions and Post-conditions (for example, STRIPS).
- Operational. These are the computational instructions, and operate on the states of some abstract machine.
- Denotational. Each element of the language syntax is assigned a relationship to an abstract mathematical entity, i.e. its denotation. For example: semantics defined for Modal Logic Syntax.

3.4 Omission in implicature

Omission in implicatures has been studied before, in linguistic interactions.
According to Swanson [36], this kind of implicature is defined as follows:

Definition 3.2. *Omissive implicature*:
In some contexts, not saying p generates a conversational implicature: that the speaker didn't have sufficient reason, all things considered, to say p.

4 Research proposal

4.1 Problem Statement

Omission or intentional silence is a phenomenon barely studied from a computational point of view whose interpretation can benefit communication processes, particularly in the interaction during the dialogue, and can help decision making.

The problem consist of automating the interpretation of the omission or intentional silence in written interactions under the contexts of testimonies and dialogue to make inferences without breaking the communication.

As part of the results, we expect to reformulate automatically a logical program K (speech acts, rules or actions) based on the information inherent in the intentional silence obtaining an equivalent program K' that will have fewer rules than the original program as a case of non-monotonicity. That is to say:

Let K and K' two logical programs with Says() predicates $\in X$ and $X \subset K$.
If K' == ($K - X$) *such that* K *is silenced then* K' *is a reduction of* K.

4.2 Research questions

1. What is the typology and the classification of silence from a computational point of view?
2. What is the semantics of the intentional silence?
3. Can the Cooperative Principle of Grice be extended to incorporate the omission or intentional silence as part of an implicature?
4. Is there any benefit of the interpretation of intentional silence in agent interaction?
5. Can the interpretation of intentional silence benefit decision making?

4.3 Hypothesis

The interpretation of omission or intentional silence in implicatures can benefit the communicative process in decision making.

4.4 Aim

Show that intentional silence during the communicative process contains valuable information that can be used for decision making.

4.5 Key objectives

1. Incorporate intentional silence as part of implicature.
2. Define the semantics, typology and classification of silence.
3. Model the meaning or meanings of silence for decision making in the case of testimonies.
4. Implement the model aimed to agent interaction in the case of dialogues.

4.6 Contributions

From a computational point of view, the contributions will be the following:

- Typology and silence classification
- Semantics and models for intentional silence
- Experimental results in interactions
- Implementations
- Non-monotonicity proofs

5 Methodology

The methods for research can be theoretical or practical. A methodology can combine various methods to be deductive, inductive or abductive. The deduction leads us from the general to the particular, the induction from the particular to the general and the abduction, known as the inference of the discovery, which being creative helps us to move from the effect to the cause. The characteristics of creative abduction are:

1. The hypothesis must be presented as a conjecture subject to empirical validation.
2. Each and every one of the predictions produced based on that hypothesis should be tested.
3. Both successes and failures will be taken into account in order to evaluate.

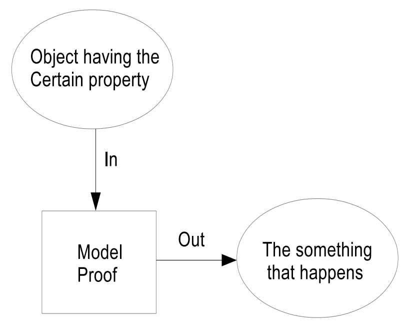

Figure 6. A model proof for the Choose method.

In mathematics, there is a wide variety of proof techniques to prove that $A \rightarrow B$ such as Direct, Indirect, Contradiction, Contrapositive, Construction, Induction, etc. [33]. As part of that list is the Choose Technique that works forward from A and the fact that the object has certain property (see Fig. 6). This also works backward from the something that happens.

For computational linguistics, there are collections or linguistic corpus, for example SCARE (Situated Corpus with Annotated Referring Expressions [35]), that are used to perform experiments, there are also simulators that allow metrics to be obtained. In particular, GIVE (Generating Instructions in Virtual Environments) is a natural language generator for evaluation purposes [5].

Research development is carried out according to the following methodology:

- Identification of the typology of silence from the computational point of view
- Proposal for the classification of silence
- Identification of semantic elements
- Definition of silence semantics

5.1 Testimonies

The following components are considered for the application of the Choose proof technique for the case of testimonies (see Fig. 7):

- Design of experiments with knowledge representation:
    1. Identification of case studies
    2. Representation with predicates
    3. Knowledge bases
- Development of programs (applied logic):
    1. Logic programming
    2. Meta-programming

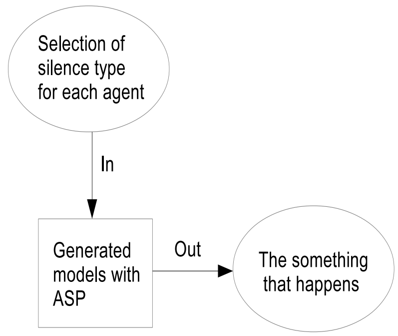

Figure 7. Choose proof for testimonies.

- Generation of models and their analysis:
    1. Answer set programming
    2. Contextual analysis
- Verification of results, dependent on the context, and feedback

This detailed process is showed in Fig. 8.

5.2 Dialogues

Challenge and evaluation type GIVE for the case of dialogues with the following variants:

- Here and now.
- With preview information.

This process is showed in Fig. 9

CORPUS	SOURCE	CONTEXT Y PRECONDITIONS	PROCESS	KEY QUESTIONS
Logic puzzles The solutions to some of these problems could have practical repercussions	Specialized bibliography • Puzzles with testimonies • Source code	• Selection of puzzle • Formalization of testimonies and common sense rules • Problem solving with logic programming • Analysis and feedback	1. Silence type Selection 2. Omission modeling and its variants 3. Analysis and feedback	• All cases have a solution? • Are there models that contain the answer to the original problem? • What consequences does the use of silence have?

Figure 8. Detailed process for testimonies.

CORPUS	SOURCE	CONTEXT Y PRECONDITIONS	PROCESS	EVALUATION
Dialogue games Rule-governed interactions between two or more players doing written statements	Software A text-adventures game or computer program that simulate a physical environment	• Source program & selection of dialogue • Maps, objetives and tasks • Formalization of statements • Programming	1. BEGIN dialogue 2. Interact 3. Restricted random insertion of an omission with it interpretation 4. Continue interaction 5. END dialogue	• Did not lose the sequence of the dialogue ? • Does the program solved the omission ? • Does the dialogue ended ? Metrics: Percentage of success

Figure 9. Elements of evaluation type GIVE for dialogues.

6 Preliminary results

We have initiated some of the objectives following the methodology in two directions: Testimonies and dialogues.

6.1 A Classification of Silence

After reviewing some previous studies on implicature and silence, we now detailed a classification that serve to understand the types interpreted in this research. Kurzon [20] proposes a first taxonomy that served to further development. We start from such taxonomy to include some contexts from our findings during the literature review as well as our proposed semantics, as Fig. 10 illustrates.

Silence is a diverse and intangible object that we learn to interpret within the context in which it appears. In this first classification, we show the following three contexts: Socio-cultural, in the Arts, and Interactive. Silence in the socio-cultural context is related to religion or the beliefs of ethnic groups [2]. Silence in the interactive context or omission refers to what could have been said and for some reason was not said [36]. Silence in the arts context is related with the temporal arts, such as music and literature, as developed by Khatchadourian [19].

Interactive silence or omission can be:

- Unintentional. The reasons for the non-intentionality of silence in the communicative process can be:
  - The noise. For example, the hearer could perceive a "silence" because of the engine of a vehicle passing by [9].
  - The forgetfulness. When unintentionally, we give incomplete information.
  - Psychological. Possibly caused by a trauma.
- Intentional. Intentional silence is sent voluntarily and intentionally received [9].
  - In group. This silence occurs when several people are involved in a situation or interaction and is not dialogic.
  - Face to face. This silence is dialogical, i.e. between two agents and intentional silence is understood as *Yes*, *No* [20], or something that requires clarification. This is called contextualized polarity.
  - Evasive. Characteristic of politicians who prefer to talk about anything else, instead of answering directly a question.

The In-group silence is the context where we place our interpretations, for instance in group chat or a crime case involving testimonies of several people. The defensive silence has two variants linked to the "right to remain silent", the acquiescent silence has three variants linked with the old saying "silence is consent" and the pro-social silence is related to the silence of employees for loyalty in the context of a company [8].

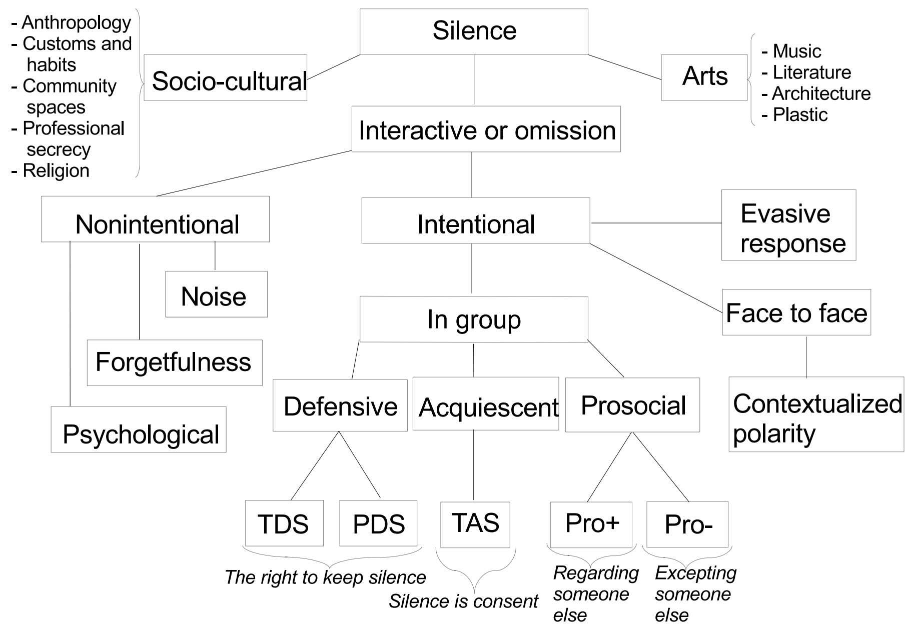

Figure 10. Some contexts where silence appears.

6.2 Our definitions

We use special symbols to refer to silence. For the silence that was before and after the word, i.e. absolute silence, we employ the symbol Ξ, for the silence relative to a context, we use the symbol ξ.

We define the predicate "says" in the sense of Grice [16], as:

Definition 6.1. *Says(a, p)*, it expresses that the agent a says p (predicate). A predicates set "says" can have a SaysGraph associated.

In the following examples, we assume that agents $Anne, Bob, Cane \in A$, also we have predicates *friend* and *hate* $\in P$.

Example 6.1. Agent $Anne$ declares that agents *Bob and Cane are friend*, symbolically we have:

$$agent(Anne; Bob; Cane).$$
$$says(Anne, friend(Bob, Cane)).$$

Definition 6.2. A $SaysGraph =< V, Ap >$, where *V* is a set of agents and *Ap* is a set of Predicate Arcs.

A SaysGraph represents the relations of the subset X (Says) of a program K, that is, it is a graphic representation of statements or testimonies of the corresponding agents.

Definition 6.3. A *Predicate Arc* is a directed arc, the origin of the arrow is labeled with a predicate and corresponds to the agent asserting something. The destination or destinations correspond to the agent or agents referred to. If the origin of the arrow is a black dot, the predicate includes, as an argument, the same agent that asserts.

An example of *SaysGraph* with *Predicate Arcs* is showed in Fig. 14.

Let K be a logic program or a knowledge base (K). $A = \{a_1,\ a_2, \ldots,\ a_n\}$ are agents. $P = \{p_1,\ p_2, \ldots,\ p_m\}$ are possible embedded predicates in a context; $X_{a_1} = \{Says(a_1, p_1), ..., Says(a_1, p_j)\} = \{Says(a_1, *)\}; \ldots; X_{a_i} = \{Says(a_i, *)\}$;$X_a$ is everything that a can say ($a \in A$); $X = X_{a_1} \cup X_{a_2} \cup \ldots \cup X_{a_n};\ (1 \leq i \leq n);\ (1 \leq j \leq m);\ X \subset K$. Whereas K contains the context definition and this has its own silence ξ then $\xi \subset K$.

For the omission relative to a *predicate p* we denote it as ξ_p and the relative to an *agent a* we write it as ξ^a.

According with the definition of *Omissive implicature* (Def. 2.2), the silenced predicates correspond to p, that is $p = Says(a, p)$ with $a \in A$ and $p \in P$, what is not said or $Says(a, \xi_p)$. This fact encourages changes in the knowledge base that are highlighted in blue, in the examples of definitions that are formulated below.

For our definitions, we assume the following. K is a logic program or knowledge base, n ($|A| = n$) is the number of interacting agents, and $X_a = Says(a, *)$ is all that the a agent Says, i.e. asserts.

Defensive Silence consists of withholding relevant ideas, information, or opinions as a form of self-protection, based on fear [8]. We define two types of defensive silence as follows.

Definition 6.4. K_a is *Total Defensive Silence (TDS)* of a understood as:

$$K_a = K - X_a$$

Where $a \in A$.

Example 6.2. Suppose that $a = Anne$.

K :		K_a :
...		...
Says(Anne, friend(Anne,Cane)).		Says(Anne, ξ).
Says(Anne, hate(Bob,Cane)).		Says(Bob, hate(Anne, Cane)).
Says(Bob, hate(Anne, Cane)).	$\longrightarrow$	Says(Cane, friend(Bob,Cane)).
Says(Cane, friend(Bob,Cane)).		...
...		

Definition 6.5. $K_{a,p}$ is *Partial Defensive Silence (PDS)* for a understood as:

$$K_{a,p} = K - \{Says(a, p)\}$$

Where: $a \in A$ and $p \in P$. Equivalently, we include $Says(a, \xi_p)$ in $K_{a,p}$.

Example 6.3. Suppose that $a = Anne$ and $p = hate$.

K :
...
Says(Anne, friend(Anne,Cane)).
Says(Anne, hate(Bob,Cane)).
Says(Bob, hate(Anne, Cane)).
Says(Cane, friend(Bob,Cane)).
...

$\longrightarrow$

$K_{a,p}$:
...
Says(Anne, friend(Anne,Cane)).
Says(Anne, ξ_p).
Says(Bob, hate(Anne, Cane)).
Says(Cane, friend(Bob,Cane)).
...

It is important to note that all kinds of intentional silence defined here have a representation in terms of ξ, which we omit in some cases for practical purposes, the silence that is not intentional is not represented.

Acquiescent Silence expresses witholding relevant ideas, information, or opinions, based on resignation [8]. In this case, three types of silence are defined.

Definition 6.6. K'_a is *Total Acquiescent Silence (TAS)* for a understood as:

$$K'_a = K_a \cup (\{Says(\bar{a}, *)\} \circ \lambda)$$

Where K_a is *TDS* for a, $(a \neq \bar{a})$, $\lambda = \{a/\bar{a}\}$, and $a, \bar{a} \in A$. The operator $\circ$ with λ substitution denotes the replacement of $\bar{a}$ for a, leading to a new subset $Says$.

Example 6.4. Suppose that $a = Bob$ and $\bar{a} \in \{Anne, Cane\}$.

K :
...
Says(Anne, friend(Anne,Cane)).
Says(Anne, hate(Bob,Cane)).
Says(Bob, hate(Anne, Cane)).
Says(Cane, friend(Anne,Bob)).
...

$\longrightarrow$

K'_a :
...
Says(Anne, friend(Anne,Cane)).
Says(Anne, hate(Bob,Cane)).
Says(Bob, ξ).
Says(Bob, friend(Anne,Cane)).
Says(Bob, hate(Bob,Cane)).
Says(Bob, friend(Anne,Bob)).
Says(Cane,friend(Anne,Bob)).
...

Definition 6.7. $K'_{a,b}$ is *Partial Acquiescent Silence of a Regarding (PAS+) agent* b understood as:

$$K'_{a,b} = K_a \cup (\{Says(b, *)\} \circ \lambda)$$

Where K_a is TDS for a, $\lambda = \{a/b\}$ and $a, b \in A$. The operator $\circ$ with λ substitution denotes the replacement of b for a leading to the new $Says$ subset.

Example 6.5. Suppose that $a = Anne$ and $b = Bob$. In this case, agent a agrees with what agent b says.

K :
...
Says(Anne, friend(Anne,Cane)).
Says(Anne, hate(Bob,Cane)).
Says(Bob, hate(Anne,Bob)).
Says(Bob, hate(Anne, Cane)).
Says(Cane, friend(Anne,Bob)).
...

$\longrightarrow$

$K'_{a,b}$:
...
Says(Anne, ξ^b).
Says(Anne,hate(Anne, Bob)).
Says(Anne,hate(Anne,Cane)).
Says(Bob, hate(Anne,Bob)).
Says(Bob, hate(Anne, Cane)).
Says(Cane, friend(Anne,Bob)).
...

Definition 6.8. $K'_{a,b}$ is *Partial Acquiescent Silence of* a *Excepting* b *(PAS-)* understood as:

$$K'_{a,b} = K_a \cup (\{Says(c, *)\} \circ \lambda)$$

Where $b \neq c \ \forall c \in A$; c is the unreliable agent; K_a is TDS for a; $\lambda = \{c/a\}$, and the operator $\circ$ with λ substitution denotes replacement of c for a on Says subset of agent a.

Example 6.6. $a = Cane$ and $b = Bob$. In this case agent Cane agrees with everyone except what Bob says.

K :
...
Says(Anne, friend(Anne,Cane)).
Says(Anne, hate(Bob,Cane)).
Says(Bob, hate(Anne,Bob)).
Says(Bob, hate(Anne, Cane)).
Says(Cane, friend(Anne, Bob)).
Says(Cane, friend(Bob,Cane)).
...

$\longrightarrow$

$K'_{a,b}$:
...
Says(Anne, friend(Anne,Cane)).
Says(Anne, hate(Bob, Cane)).
Says(Bob, hate(Anne, Bob)).
Says(Bob, hate(Anne,Cane)).
Says(Cane, ξ^b)
Says(Cane, friend(Anne,Cane)).
Says(Cane, hate(Bob, Cane)).
...

The BDI architecture can be useful in some cases to carry out the logical interpretation of the omission. The objective (Desire) corresponds to the solution of problems through the generation of models, each type of omission have an Intention that forces the updating of a knowledge base (Belief). Here, as Cohen and Levesque [7] did, the term "intention" is used in the sense of future-directed intentions.

We decided to work on the previous concepts with some puzzles that contain the objects and relations under study. Here we use the following:

1. *A Poisoning* is a puzzle of Wylie [39] where four men were eating dinner together in a restaurant when one of them was poisoned.

2. *Mystery* is a puzzle about a murder and three suspects who give their testimony [14].

3. *Knights and knaves* is a puzzle that refers to an island where each inhabitant either only tells the truth (knight) or only lies (knave) [32]. This puzzle have several variants [31].

These puzzles involve two parties - the questioner and the respondent. The questioner should interpret silence of the respondent to differentiate of a third party, as Walton suggests in an argumentation, where the third party plays the role of listener and evaluator [38].

6.3 Testimonies

Given the complication to access a collection of actual testimonies or dialogues where to evaluate the different interpretations, we recur to puzzles that include some kind of testimonies of agents and require reasoning for their solution.

6.3.1 A Poisoning

There is a puzzle taken from [39], here on referred as *Poisoning*, with the attributes to model and explore our interpretations of silence. In this puzzle, a mystery related to the murder of a person is raised, where one can assume that an officer requests and records the testimony of three suspects:

Four men were eating dinner together in a restaurant when one of them suddenly struggled to his feet, cried out "I've been poisoned," and fell dead. His companions were arrested on the spot and under questioning made the following statements, exactly one of which is false in each case:

Watts:
1) I didn't do it.
2) I was sitting next to O'Neil.
3) We had our usual waiter today.

Rogers:
1) I was sitting across the table from Smith.
2) We had a new waiter today.
3) The waiter didn't do it.

O'Neil:
1) Rogers didn't do it.
2) It was the waiter who poisoned Smith.
3) Watts lied when he said we had our usual waiter today.

Assuming that only Smith's companions and the waiter are implicated. Who was the murderer?

To find the solution of *Poisoning*, a matrix is used in [39], where possibilities are discarded while adhering to the constraint that only one statement (S) of each suspect is false. The combination of truth values False (F) and True (T), with no contradiction, allowing to reach the solution (O'Neil), is presented in Table 1.

Table 1. Solution of Poisoning puzzle

Suspect	S_1	S_2	S_3
Watts	T	T	F
Rogers	F	T	T
O'Neil	T	F	T

The case of Poisoning is represented for the analysis in terms of the predicate Says(), as previously defined, with a third parameter that affirms (1) or denies (0) the assertion, according to the original statement.

This predicate is interpreted in the sense of Grice's conversational implicature. The statements are represented as follows:

$W_1.says(watts, murderer(watts), 0).$
$W_2.says(watts, sitting\_next(watts, oneil), 1).$
$W_3.says(watts, new(waiter), 0).$
$R_1.says(rogers, sitting\_next(rogers, smith), 0).$
$R_2.says(rogers, new(waiter), 1).$
$R_3.says(rogers, murderer(waiter), 0).$
$O_1.says(oneil, murderer(rogers), 0)$
$O_2.says(oneil, murderer(waiter), 1)$
$O_3.says(oneil, new(waiter), 1)$

From this set of statements, we can easily identify the following contradictions: $\{W_3, R_2\} \vdash \perp$; $\{R_3, O_2\} \vdash \perp$; and $\{W_3, O_3\} \vdash \perp$

6.3.2 Defensive Silence in Poisoning

If an agent investigating a case faces this kind of silence of one or more of those involved, he can not count on their testimonies. So, for our case study, we have to remove the declaration of those people, as a rule in an analysis.

So, if we ignore for a moment the central constraint of the puzzle (i.e. that one of the statements is false), and we assume that somebody decides to defend himself by remaining silence. Then, to proceed we have to consider each person giving testimony, silence him, i.e. bring into consideration a total defensive silence (TDS). This does not lead to a solution, given the contradictions that emerge, as shown below:

1. When Watts is silent: $\{R_3, O_2\} \vdash \perp$
2. When Rogers is silent: $\{W_3, O_3\} \vdash \perp$
3. When O'Neil is silent: $\{W_3, R_2\} \vdash \perp$

However, by recalling the central constraint that requires to consider statements in pairs, we can explore the combinations, as depicted in Figure 11, for the TDS of Rogers. In this forest, we can observe cases where possible solutions can be reached, such as W_1W_2 with O_1O_2, and other leading to contradictions, such as W_1W_3 with O_1O_3.

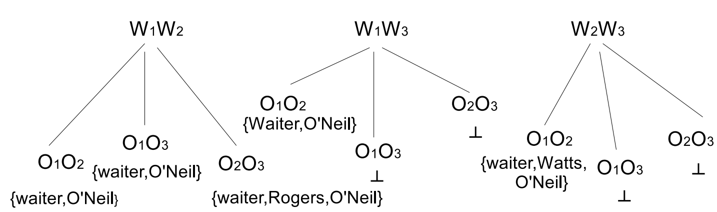

Figure 11. Pair combinations for TDS of Rogers.

The main constraint of the puzzle allows devising a strategy based on partial defensive silence (PDS) to reach solutions. We have to silence one or two out of three statements, of each of those involved in Poisoning

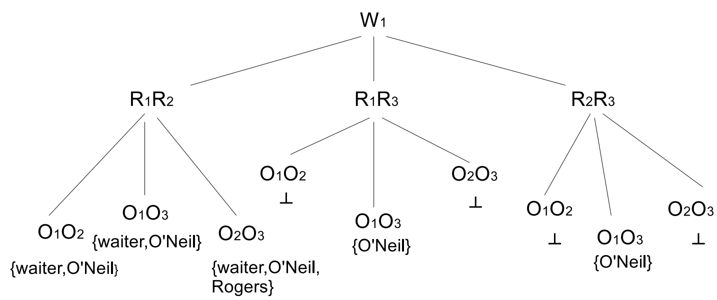

Figure 12. PDS for Statements 2 and 3 of Watts.

(i.e. 3). We will have a total of 216 (6^3) possible combinations, where one of them is presented in Fig. 12. However, we can reduce the number to 3^3 by taking pairs, for instance, analyzing for Watts, we can note that the PDS for W_1 and the PDS for W_2 there is no solution due to contradictions. On the other hand, the PDS for W_3 does have models that include the solution to the original puzzle and whose path is the dotted line in the tree in Fig. 13, where the omitted statements are W_3 of Watts, R_1 of Rogers, and O_2 of O'Neil. Interestingly, a second way to find O'Neil as causing the poisoning emerged, by replacing statement R_2 by R_1, that is false but does not contradict any other statement. Notice also that the other models reached in the analysis (non-contradiction leaves in the tree) involve, besides O'Neil, to the waiter.

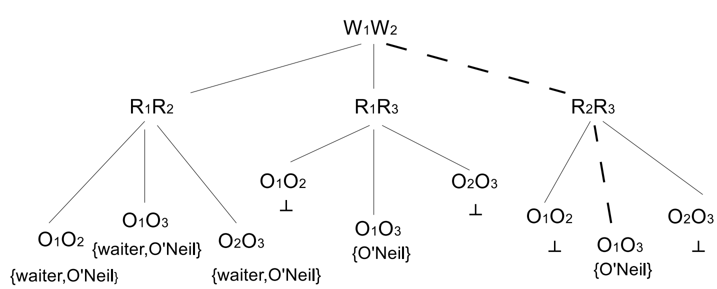

Figure 13. PDS for Statement 3 of Watts.

As a consequence of bringing the semantics of defensive silence, specifically PDS, in this puzzle, we reached the solution summarized in Table 2.

Table 2. Solution Models for Poisoning

Suspect	S_1	S_2
Watts	W_1	W_2
Rogers	R_1/R_2	R_3
O'Neil	O_1	O_3

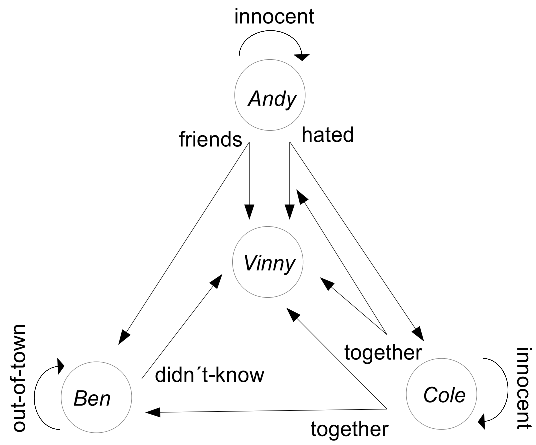

Figure 14. SaysGraph for original puzzle

6.3.3 A Mystery

The Mystery puzzle, previously modeled and solved in [14] includes testimonies of different people, and allows to model and explore our two interpretations of silence. In this puzzle, a mystery related to the murder of a person is raised, where one can assume that a judge requests and records the testimony of three suspects: *Vinny has been murdered, and Andy, Ben, and Cole are suspects.*
Andy says he did not do it. He says that Ben was the victim's friend but that Cole hated the victim.
Ben says he was out of town the day of the murder, and besides he didn't even know the guy.
Cole says he is innocent and he saw Andy and Ben with the victim just before the murder.

Figure 14 presents the testimony of the suspects through the predicate Says() as a SaysGraph. We must assume that all the people involved tell the truth except, possibly, the murderer. The story and testimony of these three people is formulated in the program Mystery.lp for Clingo.

The program for the puzzle produces as a result: murderer(ben). This means that according to the testimonies and the rules of common sense knowledge provided, the murderer is Ben.

Applying the TDS to each person giving his testimony and executing the Python program:

```
t_def_silence(Mystery.lp,andy)
t_def_silence(Mystery.lp,ben)
t_def_silence(Mystery.lp,cole)
```

and Clingo, we get those presumable guilty. That is, as a result of the silence of a person, we can analyze who becomes as candidate to blame. The possible outcomes (guilty) when a one or more suspects decide intentionally to omit their testimonies are presented in Table 3. In this, we can notice that the culprit can be anyone depending on who decides to remain silent. This would be an expression of *the right to keep silence*.

For the possibilities, we can comment:

1. {} corresponds to the original scheme where nobody is silent, i.e. every testimony is taken into account. The only model for this case is Ben, as before.

2. When Andy is silent, the offender turns out to be either Ben or Cole. Each answer corresponds to a model, as shown below:

Table 3. Total Defensive Silence model for agent

Silent agent(s)	Presumable culprit
{}	{ben}
{andy}	{cole, ben}
{ben}	{cole, ben, andy}
{cole}	{ben, andy}
{andy, ben}	{cole, ben, andy}
{ben, cole}	{cole, andy, ben}
{andy, cole}	{cole, ben, andy}
{andy, ben, cole}	{cole, ben, andy}

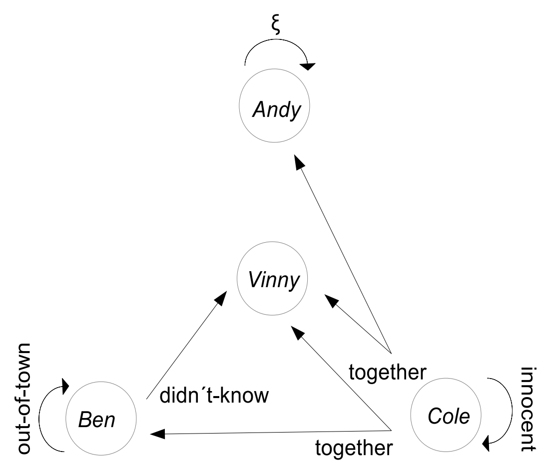

Figure 15. SaysGraph for Andy's TDS

```
Answer: 1
murderer(cole).
Answer: 2
murderer(ben).
SATISFIABLE
```

The last line indicates that there are no more models.

Figure 15 show the Total Defensive Silence for Andy.

3. When Ben is silent, any of the three suspects may be guilty. Intuitively we can think that Ben's silence has more decision capability since anyone involved can turn out as guilty.

4. Cole's silence can turn Andy or Ben guilty.

5. With the remaining possibilities, related to more than one person, any of the three involved can be guilty.

About the problem in general, we can add that Andy's silence can be in his own benefit, in the same way as Cole.

For instance, in the case of Andy, in terms of logic programming, the rules that have to be deleted are: $\{Says(andy, *)\}$.

The second interpretation of silence, Total Acquiescent Silence (TAS), is related with the old saying *silence is consent*, expressing a passive disengaged attitude, previously defined. In this interpretation, we

Table 4. Total Acquiescent Silence for agent

Silent agent(s)	Presumable culprit
{}	{ben}
{andy}	UNSATISFIABLE
{ben}	{ben}
{cole}	UNSATISFIABLE
{andy, ben}	{ben, andy}
{ben, cole}	{ben, cole}
{andy, cole}	{cole, andy}
{andy, ben, cole}	{cole, ben, andy}

operationalize it by omitting the whole person's testimony and inserting new rules related with what he is implicitly assuming with his silence. For example, in the case of Ben, we execute the programs:

```
acq_silence(Mystery.pl,ben)
```

which leads to:

1. Ignore the following assertions, since he is not declaring anything:
   $\{Says(ben, p_i)\}, (1 \leq i \leq 2)$.

2. Add the following assertions, to model his consent on what others say:
   $Says(ben, q)$, where $\{Says(A, q)\} \subset P$ and $A \neq ben$.

```
clingo 0 Mystery-as-ben.pl
```

The answer was similar to model of the original problem.

Figure 16 show the Acquiescent Silence for Ben. Table 4 shows the solutions reached for the puzzle when one or several persons are silenced under the interpretation of Total Acquiescent Silence, that is to say, *Silence is consent*. Again, the first line corresponds to the original situation where everybody has declared, leading to Ben as the muderer.

Notice that there is no model (solution) in cases 2 and 4, where Unsatisfiable is obtained. These situations can be interpreted that there is no evidence to blame any of the suspects, possibly leading to a mistrial. So, under this scheme, Andy and Cole are those who could benefit from remaining silent.

In cases 5, 6 and 7, the person who speaks is out of suspicion. In the latter case, as expected from common sense, when everybody is silent (no one has revealed any information), anyone can be the culprit.

With the combination of silences, we obtain a single model as a result for each case, and one can observe *silence is consent* as expressed by TAS (Fig. 17).

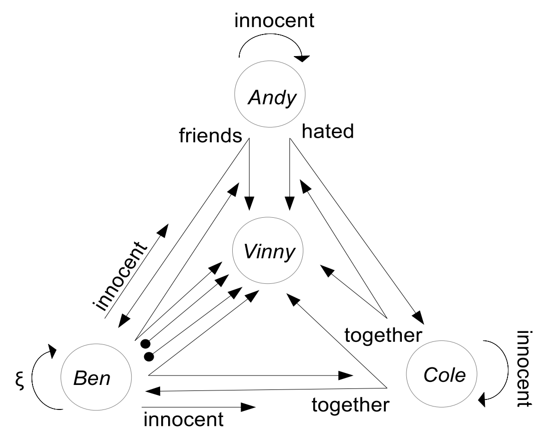

Figure 16. SaysGraph of Ben's TAS

TDS	TAS	Declarant	Presumable culprit
andy	ben	cole	{ben}
andy	cole	ben	{cole}
ben	andy	cole	{andy}
ben	cole	andy	{cole}
cole	andy	ben	{andy}
cole	ben	andy	{cole,andy,ben}

Figure 17. Combining the two types of silence.

6.3.4 Procedure

We now formulate a strategy for bringing intentional silence in the analysis of problems involving testimonies. Assuming that testimonies of different people involved are already available, the strategy (see Fig. 18) is formulated as follows:

1. Identify agents and predicates.
2. Formalize the statements using the predicate "Says".
3. Add definitions and common sense rules according to the problem at hand.
4. Identify the types of silence ocurring in the problem.
5. Generate a KB to model the problem, including agent statements, common sense knowledge, and identified types of silence. Depending on the type of silence of the agents, one or more of the following programs have to be executed, for the corresponding agent, to define the knowledge base accordingly:

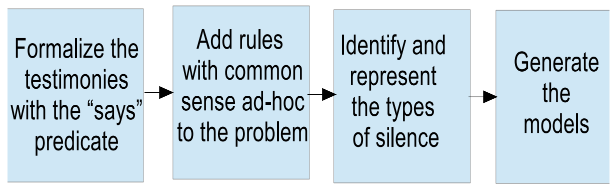

Figure 18. Strategy for the analysis of testimonies.

```
t_def_silence(kb.pl,agent)
p_def_silence(kb.pl,agent, predicate)
acq_silence(kb.pl,agent)
```

6. Apply ASP to get the models taking into account the corresponding acts of silence on the KB:

```
clingo 0 kb.pl
```

7. Analyze the different scenarios obtained.

A key step in the strategy is 4. Here, the obvious case is when one of those involved recurs to his right to remain silent. We can then proceed to consider, one at a time, the two types of silence for such person.

However, other situations can emerge, for instance when two declarants A and B separately coincide in statements *p* and *q*, but let say A in addition declares *r*. We can then hypothesize an acquiescent silence of B, or even a partial defensive silence, since he is omiting *r*, and proceed accordingly to represent and analyze the problem.

A puzzle is analyzed to illustrate the application of the strategy whose steps can also be adapted to the BDI model as shown in Fig.19. The analysis of an alternative solution of this puzzle is found in [13] . The puzzle is formulated as follows [32]:

The Island of Knights and Knaves has two types of inhabitants: knights, who always tell the truth, and knaves, who always lie. One day, three inhabitants (A, B, and C) of the island met a foreign tourist and gave the following information about themselves:

- *A said that B and C are both knights.*
- *B said that A is a knave and C is a knight.*

What types are A, B, and C?.

1. Agents: a, b and c. Predicates: knight and knave.
2. From the agent declarations, the following assertions are obtained, expressed in terms of predicate says:

```
says(a,knight(b)).
says(a,knight(c)).
says(b,knave(a)).
says(b,knight(c)).
```

3. Definitions and common sense knowledge:

```
knave(P) :- agent(P), says(P,S), S==False.
knight(P) :- agent(P), not knave(P).
1{knight(P);knave(P)}1 :- agent(P).
:- knave(a),knight(b),knight(c).
:- knave(b),knave(a),knight(c).
```

4. Given that the declarations of A and B differ, the silence to consider is defensive.

5. Two programs to execute to set silence, one at a time.

```
t_def_silence(knight-knave.pl,a)
t_def-Silence(knight-knave.pl,b)
```

6. And then to obtain answer sets, again execute one at a time.

```
clingo 0 knight-knave-tds-a.pl
clingo 0 knight-knave-tds-b.pl
```

7. The solution to the puzzle as formulated is: *knave(a), knave(b), knave(c).*

   After defensive silence of A, we got:

   - *knave(b), knight(a), knave(c).*
   - *knave(b), knight(a), knight(c).*
   - *knave(b), knave(a), knave(c).*

   And after defensive silence of B, we obtained:

   - *knave(a), knave(b), knave(c)*
   - *knave(a), knave(b), knight(c)*
   - *knave(a), knight(b), knave(c)*

   Under both scenarios analyzed, we got the solution of the original puzzle, i.e. the three agents are knaves. In addition, we can observe that agent C does not give information, which can be interpreted as unintentional silence. With the intentional silence of agents A and B, agent C maintains a constant behavior.

   Considering silence in this puzzle led to conclude that (total) defensive silence benefits the agent who practices it.

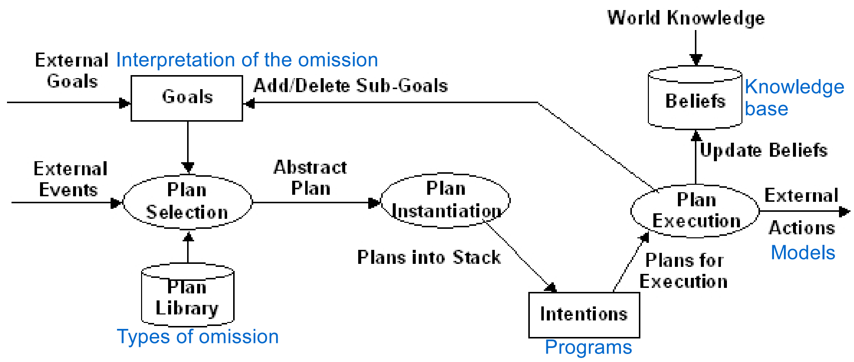

Figure 19. BDI model for testimonies.

6.4 Dialogues

The dialogue arises when one of the possible interlocutors breaks the silence with some statement initiating a sequence of interactions that include the relative silence ξ, inside which they can be some transcription keys (subsection 3.3), which is interpreted according to the context to continue until the dialogue ends.

General form of a symbolic sequence for an interaction in our syntax is: $[\Xi\xi[says(a,p)|\xi]^{*}\xi\Xi]$ where Ξ is absolute silence, ξ is relative silence, $a \in A$ and $p \in P$.

6.4.1 Towards dialogue games

- We will use a software as Frolog for analysis of conversational implicatures [3] that allows us to work:
  - Tacit act
  - Mutual information
  - Smart interaction

  Fig. 20 shows an example of dialogue.
- Figure 21 shows 8 significant situations in relation interpretation of intentional silence.
- SA corresponds to Silent Agent, RA to Reader Agent and SAI to Silent Agent Intention.
- Example for first case:

  A team member (RA) asks another (SA):

  Did you finish your part of the project?

  The SA is silent and intentionally sends the sign NOT.

  The RA recognizes that the SA answered with all intention (SAI = ’+’).

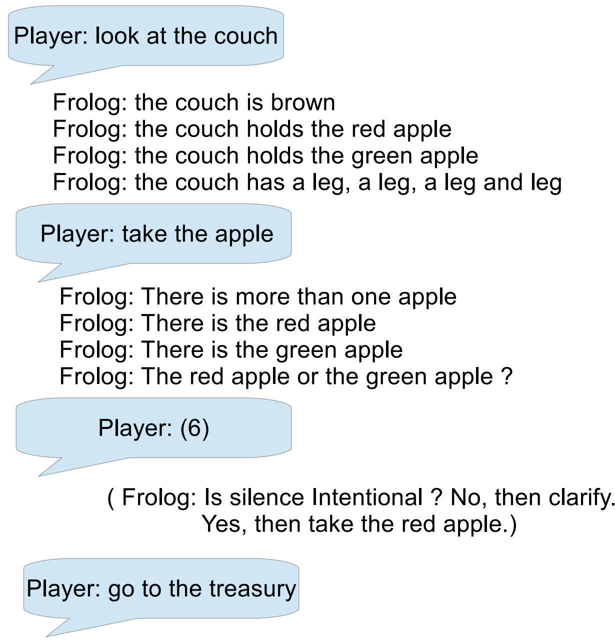

Figure 20. Omission in dialogue

- In Fatio protocol:
  question (SA, RA, “Did you finish your part of the project?”) .

- With Says predicate:
  Says(SA, question(RA, “Did you finish your part of the project?”)).

6.4.2 Semiotics

In a communication scheme that includes the interpretation of silence in its basic form [9], the speaker has to interpret the silence that the listener sends with a certain intention. To facilitate the description between this type of inter-locution where the recipient becomes the sender and the sender in the recipient through the interpretation of silence, we distinguish who interprets the silence in the communication as the Reader Agent (RA), this is because the Semiotic prefers this term for the receiver even if it is a photograph or painting. To that who sends a signal through silence, we identify as the Silent Agent (SA). Whereas the silence can be transmitted by the Silent Agent (SA) voluntarily (+) or involuntarily (-) and received by the Reader Agent (RA) also voluntarily (+) or involuntarily (-) and taking into account that the latter can attribute to the SA an intention (SAI) regarding the sending of the signal, we have different possibilities (Fig. 21).

The following are the 8 significant situations in relation to the matrix of possibilities in Fig. 21:

1. A team member (RA) asks another (SA): Did you finish your part of the project? The AS is silent and intentionally sends the sign no. The RA recognizes that the AS answered not with all intention.

2. An office manager (RA) asks his subordinate (SA): Did you do what I asked you? The subordinate intentionally sends the sign no. The boss receives the signal and interprets that the subordinate has

SA	RA	SAI
+	+	+
+	+	-
+	-	(+)
+	-	(-)
-	+	+
-	+	-
-	-	(+)
-	-	(-)

Figure 21. Possibilities matrix.

involuntarily sent the signal, that is, the boss thinks that the subordinate does not know if the progress he made could be considered as a yes or no and that is why he remained silent.

3. In a bazaar, a woman (RA) asks her partner (SA) if she agrees to buy a picture frame. At that precise moment her partner is distracted by another position where she discovers something she was looking for a few days ago while sending voluntarily the sign no. The woman does not voluntarily capture the sign, and therefore can not know if her partner said yes or said no. Nothing excludes that later the woman realizes that she has received an intentional message and recognizes a no.

4. This case may be the same as the previous one, only the woman (RA) believes that her partner (SA) did not listen to her, that is, she sent her a signal involuntarily. Later he assumes involuntarily that the sending of the signal was unintentional.

5. A programmer (SA) working on the computer is about to be interrupted by his head of area (RA) who comes to him and says “please attend to this programming order”, to which the programmer does not answer because it is concentrated in the most delicate part of the solution to a problem, involuntarily sending the signal no. The area manager accepts and mistakenly interprets the signal as a no and thinking about taking into account the attitude of the programmer in the next installment of incentives takes the order to another programmer.

6. This can be the same case as the previous one, only that the area manager accepts the signal as a non-momentary or involuntary, because he notices the occupation of the programmer.

7. This case is similar to the number 3, with the variant that here, the couple that is suddenly distracted, does not give him time to answer the question and sends the signal without wanting it.

8. Case analogous to the previous one only that later the woman realizes that her partner was distracted and the signal she sent was unintentional.

Of the significant situations described above, the first is the clearest example of transmission of a denial or affirmation through silence since the intention of the SA is correctly received by the RA as if it were a code, the other cases are ambiguous and the difference between one and another is given by the context.

7 Preliminary Conclusions

We propose to formulate the logical interpretation of the omission as an implicature in conversations and testimonies, extending category 4 (Manner) of Grice's maxims to "remove from the darkness" the intentional silence within the framework of the Cooperative Principle (CP).

Currently, we have moved towards a semantics of intentional silence that has allowed us to model some puzzles chosen initially as case studies.

The interpretations that we have made from the defined silences and their combinations, have shown that valuable implicatures can be generated in a structured way, which can be helpful for decision making, considering the context as a fundamental basis.

We have started an analysis for modeling of intentional silence with a semiotic approach using the matrix of possibilities proposed by U. Eco, where we will be able to generate implicatures in the "here and now" focus.

The omission or intentional silence is interactive, contextual, clear, powerful and completely brief.

References

[1] Achino-Loeb, M.L.: Introduction: Silence as the currency of power. Silence: The currency of power pp. 1–22 (2006)

[2] Basso, K.H.: "to give up on words": Silence in western apache culture. Southwestern Journal of Anthropology **26**(3), 213–230 (1970)

[3] Benotti, L.: Implicature as an Interactive Process. Ph.D. thesis, Université Henri Poincaré-Nancy I (2010)

[4] Bohnet, I., Frey, B.S.: The sound of silence in prisoner's dilemma and dictator games. Journal of economic behavior & organization **38**(1), 43–57 (1999)

[5] Byron, D., Koller, A., Oberlander, J., Stoia, L., Striegnitz, K.: Generating instructions in virtual environments (give): A challenge and an evaluation testbed for nlg (2007)

[6] Cayrol, C., Lagasquie-Schiex, M.C.: Bipolarity in argumentation graphs: Towards a better understanding. International Journal of Approximate Reasoning **54**(7), 876–899 (2013)

[7] Cohen, P.R., Levesque, H.J.: Intention is choice with commitment. Artificial intelligence **42**(2-3), 213–261 (1990)

[8] Dyne, L.V., Ang, S., Botero, I.C.: Conceptualizing employee silence and employee voice as multidimensional constructs. Journal of Management Studies **40**(6), 1359–1392 (2003)

[9] Eco, U.: Signo. Labor (1994)

[10] Elster, J.: Social norms and economic theory. Routledge New York (2000)

[11] Fernández Ruiz, G.: Decir sin decir: Implicatura convencional y expresiones que la generan en español. El Colegio de Mexico AC (2018)

[12] Garbutt, J.: The use of no comment by suspects in police interviews. In: Exploring Silence and Absence in Discourse, pp. 329–357. Springer (2018)

[13] Garcés-Báez, A., López-López, A.: First approach to semantics of silence in testimonies. In: International Conference of the Italian Association for Artificial Intelligence. pp. 73–86. Springer (2019)

[14] Gelfond, M., Kahl, Y.: Knowledge representation, reasoning, and the design of intelligent agents: The answer-set programming approach. Cambridge University Press (2014)

[15] Gödel, K., Zum intuitionistischen Aussagenkalkül, A.A.d.: Wissenschaften wien, math.-naturwissensch. Klasse **69**, 65–66 (1932)

[16] Grice, H.P.: Logic and conversation. Syntax and semantics: Speech acts, Cole et al. **3**, 41–58 (1975)

[17] Grosz, B.J., Sidner, C.L.: Plans for discourse. Tech. rep., BBN LABS INC CAMBRIDGE MA (1988)

[18] Jakobson, G., Parameswaran, N., Buford, J., Lewis, L., Ray, P.: Situation-aware multi-agent system for disaster relief operations management. Proc. ISCRAM pp. 313–324 (2006)

[19] Khatchadourian, H.: How to Do Things with Silence, vol. 63. Walter de Gruyter GmbH & Co KG (2015)

[20] Kurzon, D.: The right of silence: A socio-pragmatic model of interpretation. Journal of Pragmatics **23**(1), 55–69 (1995)

[21] Kurzon, D.: Towards a typology of silence. Journal of Pragmatics **39**(10), 1673–1688 (2007)

[22] McBurney, P., Parsons, S.: Dialogue games in multi-agent systems. Informal Logic **22**(3) (2001)

[23] McBurney, P., Parsons, S.: Dialogue games for agent argumentation. In: Argumentation in artificial intelligence, pp. 261–280. Springer (2009)

[24] Mendelson, E.: Introduction to mathematical logic. Chapman and Hall/CRC (2009)

[25] Meyer, J.J., Broersen, J., Herzig, A.: Bdi logics (2015)

[26] Pearce, D.: Stable inference as intuitionistic validity. The Journal of Logic Programming **38**(1), 79–91 (1999)

[27] Rao, A.S., Georgeff, M.P., et al.: Bdi agents: from theory to practice. In: ICMAS. vol. 95, pp. 312–319 (1995)

[28] Schröter, M., Taylor, C.: Exploring silence and absence in discourse: empirical approaches. Springer (2017)

[29] Scott, R.L.: Dialectical tensions of speaking and silence. Quarterly Journal of Speech **79**(1), 1–18 (1993)

[30] Searle, J.R.: A taxonomy of illocutionary acts (1975)

[31] Smullyan, R.M.: What is the name of this book? The riddle of Dracula and other logical puzzles. Prentice-Hall (1980)

[32] Smullyan, R.M.: Forever undecided. Knopf (2012)

[33] Solow, D.: How to Read and Do Proofs an Introduction to Mathematical Thought Processes. Jhon Wiley and Sons, Inc. (2005)

[34] Spenader, J.: Speech act theory introduction to semantics. Guest Lecturer November **4**, 2004 (2004)

[35] Stoia, L., Shockley, D.M., Byron, D.K., Fosler-Lussier, E.: Scare: a situated corpus with annotated referring expressions. In: LREC. Citeseer (2008)

[36] Swanson, E.: Omissive implicature. philosophical topics **45**(2), 117–138 (2017)

[37] Von Wright, G.H.: Deontic logic. Mind **60**(237), 1–15 (1951)

[38] Walton, D.: Witness Testimony Evidence: Argumentation, Artificial Intelligence, and Law. Cambridge University Press (2008)

[39] Wylie, C.R.: 101 puzzles in thought and logic, vol. 367. Courier Corporation (1957)

[40] Zalta, E.N., Nodelman, U., Allen, C., Perry, J.: Stanford encyclopedia of philosophy (2003)