

CoPains

Cognitive Planning in Persuasive Multimodal Communication

Summary table of persons involved in the project:

Partner	Name	First name	Current position	Role & responsibilities in the project (4 lines max)	Involvement (person.month)
CNRS/IRIT	LORINI	Emiliano	CNRS researcher	Scientific coordinator, responsibilities over WP0 and WP2	16,2
CNRS/IRIT	AMGOUD	Leila	CNRS research director	Expertise in models of persuasive argumentation (WP2)	3,6
CNRS/IRIT	HERZIG	Andreas	CNRS research director	Expertise in logic and epistemic planning (WP2)	7,2
CNRS/IRIT	LONGIN	Dominique	CNRS researcher	Expertise in models of emotion (WP2)	9
CNRS/IRIT	MARIS	Frédéric	Associate professor	Expertise in epistemic planning (WP2)	1,8
CNRS/LIMSI	SABOURET	Nicolas	Full professor	Responsibility over WP5, expertise in models of personality and cognitive modelling (WP2)	7,2
CNRS/LIMSI	CLAVEL	Céline	Associate professor	Responsibility over WP5, expertise in models of personality and evaluation protocols (WP2, WP5)	10,8
LIS/AMU	OCHS	Magalie	Associate Professor	Responsibility over WP3, expertise in construction of computational models of multimodal interaction based on automatic analysis of corpora (WP1, WP3)	9,2
LIS/AMU	FOURNIER	Sébastien	Associate professor	Expertise in sentiment and emotion analysis (WP1, WP3)	6
LIS/AMU	CHIFU	Adrian-Gabriel	Associate professor	Expertise in information retrieval and corpus analysis (WP1, WP3)	7,2
LIS/AMU	BELLOT	Patrice	Full Professor	Expertise in NLP, sentiment and emotion analysis (WP1, WP3)	3,6
LIS/AMU	FAVRE	Benoit	Associate professor	Expertise in NLP and machine learning (WP1, WP3)	7,2
LPL	NGUYEN	Noël	Full professor	Responsibility over WP1, expertise in speech processing and analysis (WP1, WP3)	7,2
LPL	BERTRAND	Roxane	CNRS researcher	Expertise in H-H interaction and multimodal annotation (WP1, WP3)	7,2
LPL	BLACHE	Philippe	CNRS research director	Expertise in NLP (WP1)	3,6
LPL	PREVOT	Laurent	Full professor	Expertise in computational models of dialog, semantics (WP1)	7,2
LPL	BIGI	Brigitte	CNRS researcher	Expertise in automatic speech alignment and segmentation (WP1)	7,2
LPL	RAUZY	Stéphane	CNRS research engineer	Expertise in morphosyntactic tagging, automatic detection of dysfluencies (WP1)	7,2
DAVI	BULTIAUW	Didier	Head R&D	Responsible for agent's nonverbal reasoning development in WP4	12
DAVI	GERARD	Yannick	R&D project manager	In charge of agent's nonverbal corpus formulation in WP4	4
DAVI	DAVID	Aymeric	Research technician	Responsible for test and for experimentation of the system in WP4	10

Any changes that have been made in the full proposal compared to the pre-proposal

In the evaluation of the project pre-proposal, the ANR evaluation committee criticized the fact that, although it shows awareness of the ethical aspects, it does not provide clear indications on how this will be done and, in particular, on how it can be ensured that there will actually be the possibility to involve the relevant subjects in the experiments. We have addressed this weakness by including in the project consortium a new unit INSERM - U1093 “Cognition, Action, et Plasticité Sensorimotrice”, Université Bourgogne Franche-Comté. It will act as a subcontractor in the project and will be coordinated by France Mourey (full professor). France Mourey is member of the ethical space (“espace éthique”) Bourgogne Franche-Comté and has a long-time expertise in ethical aspects of research projects in the areas of healthcare, gerontology and geriatrics. She is also in contact with several associations of retired people who participated in previous research and development (R&D) activities in which she was involved at Espace Marey, Université Bourgogne Franche-Comté. Thanks to these contacts, she will give access to the targeted population (elderly people) for the experimental part of the project (collection of corpora and evaluation). She will also examine any possible issues regarding ethics emerging during the project and supervise the project to guarantee that the empirical analysis will be conducted in respect of the persons involved in the experiments and in conformity with the ethical standards and legislation. A letter of engagement by the INSERM unit is included in the annex of the project proposal, given as a separate document.

I. Proposal’s context, positioning and objective(s)

a. Objectives and scientific hypotheses

The goal of the CoPains project is to build artificial agents that are capable of inducing human users to adopt healthy behaviors and, if necessary, by persuading them to change their habits in their interest. More precisely, our application domain is *persuasive* technology for healthcare and assistance in which an embodied conversational agent (ECA) interacts with a person in a *multimodal* way in order to support her activity and to take care of her well-being. In order to interact with the person in an efficient way, the agent will be endowed with a sophisticated model of human cognition which will make it capable of being *persuasive* and of *planning* a strategy aimed at influencing the user’s behavior. For instance, the agent will exploit its knowledge of the user’s cognitive attitudes and affective states in order to persuade her to behave in a healthy way and to refrain from behaving in a unhealthy way (e.g., by taking a prescribed medicine, doing a regular physical activity, eating healthy food, etc.). The following are two scenarios that we expect to study and implement during the project. The first scenario is targeted at a specific category of population, namely the elderly.

Scenario 1. *R2-D2 is an artificial companion which takes care of an elderly person called Bob and keeps him company. Bob has to do regular physical activity to be in good health. The problem is that Bob prefers to stay at home watching TV or reading a book rather than to go out for a walk. In this situation, R2-D2 has to play a tutor role: it has to ensure that Bob will do regular physical activity in his interest. To this aim, R2-D2 needs to use its persuasive capabilities in order to induce Bob to adopt a healthy lifestyle. This requires a proper understanding of Bob’s mind by R2-D2 and, in particular, of the relationship between his cognitive attitudes and his actions (i.e., the way Bob’s cognitive attitudes such as his beliefs, desires and preferences determine his actions).*

Scenario 2. *A virtual assistant called BB-8 has to give useful advice about nutrition to a person called Ann. In particular, BB-8 has to support Ann in taking care of quality and quantity of food she eats every day. To this aim, BB-8 has to use its persuasive capabilities in order to induce Ann to buy good quality food and to stick to a balanced diet. In order to be successful, BB-8 has to be capable of recognizing and understanding Ann’s cognitive attitudes including her actual beliefs and preferences.*

Such persuasive technology must be able not only to present sensible arguments to the user, but also to adapt to the user’s personality, beliefs and personal goals and to manage emotions in the dialogue. For example,

suppose Bob does not want to go out for a walk because he believes that it does not improve his health and because he prefers to watch his favorite TV show. A conversational agent that wants to persuade Bob to change behaviour would need several capabilities. First, it must understand Bob's beliefs and propose counter-arguments to persuade him. Second, research in psychology (*e.g.*, Higgins, 2005) has proven that people are sensitive to different sort of arguments depending on their personalities. Thus, the conversational agent has to use personalized arguments based on Bob's personality. Third, (VanKleeef *et al.*, 2004) proved that emotions play a key role in persuasion. Thus, the conversational agent has to show different kinds of affective behaviour to improve its persuasion power.

The general objective of the CoPains project is to develop an artificial agent which is endowed with the following capacities:

- the capacity to infer the cognitive attitudes (*e.g.*, beliefs, desires, preferences, intentions) and affective states (*e.g.*, emotions, moods) of the human user from her observable behaviors,
- the capacity to influence and persuade the human user to believe something and/or to behave in a certain way, and
- the capacity to interact with the human user through multimodal communication including textual expressions and facial expressions.

In order to achieve this objective, CoPains is expected to exploit theoretical and empirical approaches by combining, in a rather innovative way, corpus-based analysis with formal methods from different areas of artificial intelligence (AI). This includes logic, planning, sentiment analysis, and data-mining. Furthermore, in order to make the artificial agent believable, CoPains will adopt an interdisciplinary stance. In particular, it will import knowledge and competences from psychology and linguistics in order to (i) drive the construction of the formal model and of the computational architecture on which the artificial agent is based, and (ii) validate them. The main scientific challenges raised by the CoPains objectives are: 1) Mental state recognition, 2) Cognitive planning and adaptation, 3) Multimodal expressive behavior for persuasion.

Mental state recognition. Mental state recognition consists in endowing the artificial agent with the general capacity of ascribing cognitive attitudes and affective states to the human user. The artificial agent will be endowed with a “*background theory*” that will allow it to infer the human user's cognitive attitudes and affective states from a given set of observables including verbal utterances as well as facial expressions. We will combine two different approaches. As for verbal utterances, we will enrich and exploit the recognition module and ontology integrated in the DAVI system that allow to extract a rather simplified version of the meaning of the verbal message. As for the analysis of the human user's nonverbal behavior (*e.g.*, head movements, smiles), we will use the Affectiva emotion detection engine (McDuff *et al.*, 2016) to recognize in real-time specific emotions of the user from a set of nonverbal signals.

Cognitive planning and adaptation. In cognitive planning, the agent has the goal that the human user will form a certain belief or intention and, consequently, she will behave in a certain way. Given its representation of the user's cognitive attitudes and affective states, the agent will plan a certain action or sequence of actions in order to achieve its goal. In the project, we will use a logical approach to cognitive planning that enriches the epistemic planning approach (Cooper *et al.*, 2016) by motivational concepts. In particular, we will use a logic of cognitive attitudes and emotions based on previous work by IRIT (Lorini, 2011; Dastani & Lorini, 2012; Adam *et al.*, 2009). We will endow the agent with a *cognitive planning module* based on the logic. The module generates plans aimed at influencing the human user to behave in a certain way, on the basis of the understanding of the relationship between the user's cognitive attitudes and affective states and her behaviors. The cognitive planning module will use not only a representation of the user's beliefs, goals, and intentions, but also a model of her personality, inspired by (Higgins, 2005) and (Faur *et al.*, 2015) to evaluate the persuasiveness impact of a given argumentation move.

Multimodal expressive behavior for persuasion. The output of cognitive planning is a plan consisting of a sequence of abstract specifications of the behavior that the artificial agent should adopt in order to achieve its

influencing goal. For example, the generated abstract plan may consist in inducing the human user to believe that “doing a regular physical activity is necessary for being in good health”. Turning such an abstract plan into a sequence of concrete multimodal expressions including both verbal utterances and facial expressions is an open research problem. We aim to build a *behavior module* taking an abstract plan as input and returning a sequence of multimodal expressions as output. The behavior module will be based on previous work by LIMSI on the formalization of negotiation dialogues (OuldOuali *et al.*, 2017) and by LSIS on nonverbal behavior (Chollet *et al.*, 2017). It will take into account the user profile (*i.e.*, her personality) in order to adapt the agent’s verbal and nonverbal responses. Indeed, research in psychology shows that interaction and persuasion are easier when context frame and user profile match (van Kleef, 2007). Moreover, in order to create an engaging interaction and then to reinforce the artificial agent’s persuasiveness, the *backchannel module* will generate verbal, vocal and nonverbal backchannel responses (*e.g.*, “hmm”, head node) during the interaction, following a preliminary research work conducted in collaboration between LPL and LSIS (Porhet *et al.*, 2017).

Figure 1 describes the general architecture of the system that we intend to develop in the context of the project. We will have the following division of labor for building its different modules: - Background “theory”: DAVI, IRIT; - Cognitive planning module: IRIT, LIMSI, DAVI; Behavior module: LIMSI, LSIS, DAVI, LPL; - Backchannel: LSIS, LPL, DAVI.

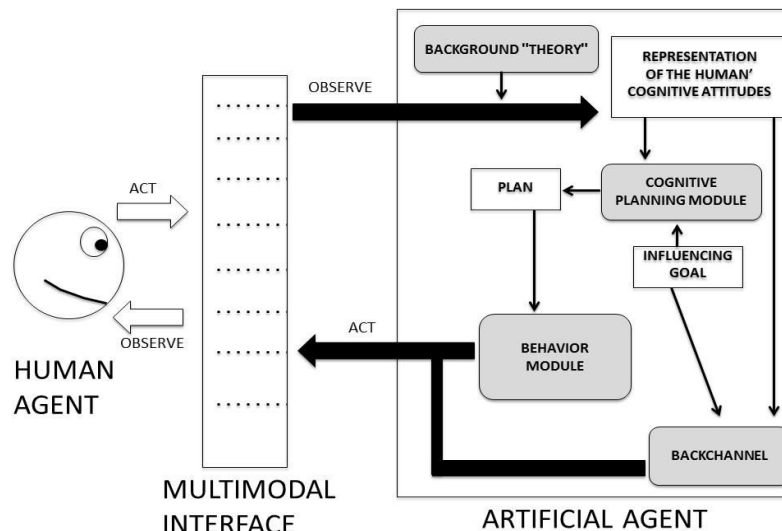


Figure 1: Architecture of the system

Let us go back to one of the previous scenarios in order to illustrate how the modules of the architecture intervene at the different stages of interaction between the artificial agent and the human. R2-D2 has to ensure that Bob does regular physical activity (*influencing goal*). It is 3:00 pm and it is less than two hours before the sunset of a winter day. R2-D2 knows that Bob has done no physical activity during the last two days. It decides to recommend to Bob to go out for a walk and generates the corresponding plan by its *planning module*. R2-D2’s *behavior module* transforms the abstract plan into the following verbal expression:

“Hey Bob! It is a great sunny day. You should take advantage of it and go out for a walk before the end of the day.”

coupled with a facial expression of joy and comfort. Bob replies as follows by expressing discontent:

“I don’t want to go out! The last time I went out for a walk it was so cold. I did not like it at all.”

R2-D2 uses its knowledge (*background theory*) to infer the following cognitive attitudes and affective state of Bob:

- Bob believes that if he goes out for a walk, he will feel cold

- Bob wants to avoid feeling cold
- Bob feels fearful and disgusted by imagining himself to go out for a walk

R2-D2 generates a new plan through its planning module aimed at reassuring Bob that there is no risk of feeling cold since the outside temperature is mild and at reminding him that going out for a walk is important for him to be in good health. Based on Bob's personality profile, the system can predict that Bob will be more sensitive to negative effects of his behaviour than to possible positive outcomes of his efforts. Thus, it decides to argue on the bad consequences of stopping physical activity. Then, R2-D2's behavior module transforms the abstract plan and arguments into the following sequence of verbal expressions:

"Bob, you shouldn't worry so much. If you go out, you won't feel cold: the outside temperature is 15°C. Moreover, you have not done any physical activity in the last two days. You know that lack of physical activity is a major cause of health problems."

coupled with an emotional facial expression.

b. Originality and relevance in relation to the state of the art

Influence is the process which consists in an agent determining, causing, affecting, etc. the mental attitudes (e.g., beliefs, opinions, preferences, intentions) and/or actions of a given individual. From this perspective, it is reasonable to distinguish between influence on mental attitudes, and influence on beliefs in particular, from influence on actions. This distinction is made explicit in literature in social psychology in which influence is defined as "... change in an individual's thoughts, feelings, attitudes, or behaviors that results from interaction with another individual or a group" (Rashotte, 2009). In the literature in social psychology, influence and persuasion are seen as tightly connected concepts (Cialdini, 2001). *Persuasion* can be seen as the intentional form of influence in which an agent (the influencer or the persuader) tries to make someone (the influencee or the persuadee) do or believe something by giving her a good reason or providing a good argument (Perloff, 2003).¹ Persuasion and influence play a crucial role in the *negotiation* process in which two or more agents try to find an agreement about the achievement of a common goal or the performance of a joint plan. Indeed, in order to be a good negotiator, an agent has to be at the same time persuasive and capable of detecting the persuasive strategies of the others.

In this section, we first discuss psychological theories of influence and persuasion that provide the theoretical background of the CoPains project. Then, we provide a critical discussion of formal and computational models of influence and persuasion developed in artificial intelligence (AI) and explain how the project is expected to improve over them.

Psychological theories of influence and persuasion

The concepts of influence and persuasion have been in the focus of research in social psychology. Social impact theory (SIT) by Latané (1981) is a psychological theory of social influence emphasizing the role of a group of people in influencing the behaviour of an individual. Social impact is conceived as the number of behavioral changes that might occur in an individual due to the presence or action of others who are real or imagined. According to this theory, social impact is determined by three main factors: the number of others who act in a certain way (*i.e.*, the number of sources), their immediacy to the target agent (*i.e.*, their temporal and spatial closeness to the influence), and their strength (*i.e.*, salience and power). According to SIT, social influence is proportional to a multiplicative function of the strength, immediacy, and number of sources. Cialdini's seminal work on the psychology of persuasion (Cialdini, 2001) has been devoted to identify some universal psychological traits and dispositions of individuals that make them persuadable. For example, according to Cialdini, there exists a family of persuasive strategies which exploit the natural tendency of individuals to persist on their current intentions in order to remain consistent with what they decided to do in the past.

¹ Not all forms of influence are intentional. For example, a person can be influenced by the way another person dresses without the latter knowing that her behavior is inducing the former to behave in a certain way. This is a typical form of conformity.

The individual's personality also plays a key role in the persuasion process. Traits like regulatory focus (Higgins, 1997), for example, have been shown to influence directly how individuals make judgements and decisions (Cesario *et al.*, 2008). Individuals are generally either promotion-focused (*i.e.*, are gain-oriented and seek for opportunities) or prevention-focused (*i.e.*, are loss-oriented and seeking to avoid failures) and make decisions accordingly. For example, promotion-focused individuals are more receptive to promotion-focused information and vice versa. Higgins (2005) has elaborated the regulatory focus theory (RFT). He has shown that a regulatory fit effect occurs when context frame and chronic focus match. This fit has two main effects on individuals: it facilitates information processing and makes individual "feel right" about the processing. Framing influences individual's cognitive processing of the messages (Lee & Aaker, 2004). Specifically, a promotion-focused individual will process faster a message emphasizing positive aspects of a product and possible gains associated with it ("Eating vegetables regularly reduces the risk of cancer"), while a prevention-focused individual will process faster a message emphasizing aspects that would decrease the probability of incurring a loss ("Eating too much added sugar increases the risk of dying with heart disease"). An individual's regulatory focus has a direct impact on her preferences (Aaker & Lee, 2004) and can be used to influence her decisions (Cesario *et al.*, 2004), as it can be activated by priming (Wang & Lee, 2006). In their meta-review, Ludolph & Schultz (2015) analyzed the use of RFT for designing health promotion messages. Results showed that it is an effective way to improve the impact of the messages on individuals' decisions.

Formal and computational models of influence and persuasion

A number of computational and formal models of influence and persuasion have been proposed in the recent years in the domains of AI and human-computer interaction (HCI). Some of them are close to the vision of the CoPains project as they also emphasize the importance of grounding a model of influence and persuasion on a solid cognitive foundation. As emphasized by (Castelfranchi, 1995), "...the general law of influencing cognitive agents' behavior does not consist in incentive engineering, but in modifying the beliefs which support goals and intentions and provide reasons for behavior".

Formal models

Formal models of influence and persuasion are mostly based on logic and argumentation.

There is a large body of literature on models of persuasive argumentation. Such models are mostly based on Walton & Krabbe's notion of persuasion dialogue in which one party seeks to persuade another party to adopt a belief or point-of-view she does not currently hold (Walton & Krabbe, 1995). These dialogues begin with one party supporting a particular statement which the other party to the dialogue does not, and the first seeks to convince the second to adopt the proposition. The second party may not share this objective. A variety of formal models of persuasive argumentation have proposed in the last twenty years. See Prakken (2006) for a general introduction to the research in this area. There exist models based on abstract argumentation (Bench-Capon, 2003; Bonzon & Maudet, 2011; Amgoud *et al.*, 2000) as well probabilistic models in which the persuader's uncertainty about what the persuadee knows about, or believes is represented (Hunter, 2015). There exist also models based on fuzzy logic and possibility theory in which a piece of information is represented as an argument which can be more or less accepted depending on the trustworthiness of the agent who proposes it (Da Costa Pereira *et al.*, 2011). Models of persuasive argumentation in the context of negotiation have also been proposed (Amgoud & Vesic, 2012).

The logical model of influence by Lorini & Sartor (2014) is aimed at formally characterizing the meaning of the expression "an agent 1 (the influencer) sees to it that another agent 2 (the influencee) sees to it that something is the case". It is a logical model of influence which is directly linked with the game-theoretic concept of extensive game.

The concept of epistemic planning has been introduced in the recent years in AI (Bolander & Andersen, 2011; Bolander *et al.*, 2015). Epistemic planning generalizes classical planning: the goal to be achieved is not a state of the world but some belief states of one or more agents. Typical goals in epistemic planning are persuasive goals, *i.e.*, the goal of inducing a certain agent to believe something.

Computational models

Computational models of negotiation exist in which the concepts of influence and persuasion play a primary role. For instance, the model presented by Panzarasa *et al.* (2002) reflects a conception of social influence as a

socio-cognitive process which consists in changing cognitive attitudes and, consequently, the behavior of an agent and, ultimately, when played out in a network of social relations, leads to the generation of interpersonal agreements among different agents. Klatt *et al.* (2011) proposed a model of negotiation in the context of AIDS prevention in which two partners have to negotiate whether they are going to have safe or unsafe sex. The model assumes that, in order to be able to come to an agreement or to even persuade his/her partner and change his/her behavior, the negotiator has to reason about his/her partner's beliefs and how they can be changed. De Carolis & Mazzotta (2017) present a computational model of persuasion dialogs in which an artificial agent can adapt its persuasive strategy to the user's personality traits and living habits. This model only considers verbal communication in which a communicative act is translated into a natural language sentence. It does not take into account the multimodal aspects of persuasive communication. In the model by Alfonso *et al.* (2015), an artificial agent can observe and predict other agents' emotions and behaviors generated by these emotions in the negotiation process. Finally, de Melo *et al.* (2011) studied the impact of emotions of anger and happiness on the outcome of the negotiation process.

Some research works have explored the potential persuasiveness of embodied conversational agents (ECAs) (Pickard, 2012; Cavazza *et al.*, 2010; Mazzotta *et al.*, 2010; André *et al.*, 2011). For instance, a companion ECA has been developed by Cavazza *et al.* (2010) to influence users' attitudes towards their daily lives and in particular relations at work. In general, research on this subject provides evidence that ECAs have the ability to influence people's attitudes and behaviors. Experiments comparing different ECA's behaviors have shown the importance of nonverbal signals (Guadagno *et al.*, 2007) but also the effects of the social context (*e.g.*, gender, social relations, etc.) (Rosenberg *et al.*, 2008).

Originality with respect to the state of the art

Formal models of persuasive argumentation in AI focus exclusively on dialogue. CoPains goes beyond these models by focusing on multimodal communication and, in particular, by combining a logic-based model of cognitive planning with a model of verbal and nonverbal behaviors aimed at persuading.

CoPains places special emphasis on another aspect that has been rather neglected in the literature on persuasive argumentation, namely, reasoning about the cognitive attitudes and emotions of the persuadee. Indeed, in order to change someone's behavior, one has to understand first of all what the other thinks, prefers, believes, etc. as well as the emotions she feels. More precisely, an adequate model of influence and persuasion on actions (*i.e.*, how an agent can induce another agent to perform a certain action) must take into account the subtle connection between an agent's cognitive attitudes and emotions, on the one hand, and her actions, on the other hand. CoPains has the ambition to provide such a model and to implement it in an artificial agent. This is another important novelty of the project with respect to models of persuasive argumentation in AI which neglect the cognitive foundation of influence and persuasion.

Another important contribution of CoPains is with respect to the area of epistemic planning. Indeed, the notion of cognitive planning studied in the project is a generalization of epistemic planning studied in AI and briefly discussed above: it is not only some belief state of a target agent that is to be achieved, but more generally a cognitive state. The latter involves not only beliefs, but also goals and intentions. Cognitive planning is a novel idea which is at the core of CoPains. It will be explored both at a theoretical level and at a practical level (Work Package 2).

CoPains will also provide novel contributions with respect to the area of persuasive technologies. Contrarily to previous research on persuasive ECAs discussed above, our objective is not to evaluate through perceptive studies the effects of different variables on the persuasiveness of an ECA. Our aim is (i) to start from a real corpus of human-human interaction in order to identify the persuasive multimodal and contextual aspects of communication (Work Package 1), (ii) to exploit the analysis of the corpus in order to build a model of multimodal persuasive communication (Work Package 3), (iii) to implement the model in an artificial agent architecture (Work Package 4), and (iv) to evaluate the artificial agent's persuasiveness (Work Package 5).

c. Methodology and risk management

We are aware that the project CoPains entails some risks at three different levels: (i) the access to the targeted population (elderly people) for one of the envisaged scenarios and corresponding case-studies illustrated

above, (ii) the ethical aspects involved in the access to this population, and (iii) the integration of the different modules of the agent architecture into an operational prototype.

Risks (i) and (ii) were raised by the ANR evaluation committee at the level of the pre-proposal. As explained at the beginning of this document, we have taken the necessary measures to include in the consortium an expert on ethical aspects of research projects in the areas of healthcare, gerontology and geriatrics. Such expertise will be provided by France Mourey, full professor at INSERM - U1093 - CAPS (Cognition, Action, et Plasticité Sensorimotrice), Université Bourgogne Franche-Comté. She will act as a subcontractor and her work will be supported by an engineer recruited in the context of the project. The presence of France Mourey in the project will also guarantee the access to the targeted population, given her contacts with several associations of retired people who participated in previous research and development (R&D) activities in which she has been involved.

As for the ethical aspects of the project, we also plan to create an ethics advisory board composed of representatives of the end-users, scientists and philosophers. The ethics advisory board, which will meet once a year, will monitor the project by continuously assessing whether any additional ethical issues or concerns surface throughout the duration of the project. Moreover, we plan to submit all experimental protocols developed during the project to a research ethics committee (see description of work package 0 below for more details).

As for risk (iii) about integration of the bricks of the agent architecture into an operational prototype, DAVI will be in charge of this integration. This industrial partner has a long-lasting sound experience and specialized expertise in software integration, AI and embodied conversational agents (ECAs). In case during the project we will encounter some difficulties in integrating all modules of the agent architecture, we will only integrate a subset of them into the DAVI system. For example, we will integrate the cognitive planning module with the verbal and nonverbal behavior module, or the (verbal and nonverbal) behavior module with the backchannel module. This hereby warrants that at the end of the project we will dispose of a first prototype of the persuasive artificial agent exhibiting some of the expected functionalities of the agent architecture depicted in Figure 1 such as, *e.g.*, the capacity of transforming an abstract persuasive plan into a rich multimodal expression. We would like to emphasize that this strategy is a guarantee of success for the project, as even in the worst-case scenario, we will be able to deliver a prototype that will be exploitable in practice at the industrial level.

Before concluding, we would like to mention another (minor) risk concerning the experimental part of the project. CoPains is about behaviour change due to persuasion, which is always difficult to measure in short-term experiments. It will not be possible, during the project, to prove the impact of persuasion on long-term behaviour change. The goal of the project is to study how multimodal persuasion adapted to the user's personality enhances the acceptance of recommendations about the adoption of a healthy lifestyle.

II. Project organization and means implemented

a. Scientific coordinator and its consortium/its teams

The consortium consists of five partners including four public research laboratories (IRIT, LIMSI, LIS, LPL) and a private company (DAVI). It also includes a subcontractor (INSERM). It has a strong interdisciplinary aspect (AI, logic, linguistics, psychology, industry).

The project will be coordinated by **Emiliano LORINI** who will dedicate 45% of his research time to the project activities. Emiliano Lorini is CNRS research scientist and co-head of the LILaC team (Logic, Interaction, Language and Computation) at the Institut de Recherche en Informatique de Toulouse (IRIT), Université Paul Sabatier. He obtained a master degree in Computer Science from Toulouse University in 2004 and a Ph.D in Cognitive Sciences from the University of Siena (Italy) in 2007. He obtained the HDR ("Habilitation à diriger des recherches") from Université Paul Sabatier in 2016. He is member of the Institute for Advanced Study in Toulouse (IAST), a Laboratory of Excellence (LabEx) at the Université de Toulouse Capitole. He has been awarded the CNRS bronze medal in 2014 for his early achievements in the area of

artificial intelligence (AI). His main interest is in the formal analysis, with the aid of logic and game theory, of the reasoning, decision-making and emotions of both human agents and artificial agents as well as of several aspects of social interaction such as the concepts of trust, reputation, power and social influence. He authored 32 articles in journals and 75 articles in international conferences and workshops in the fields of AI, logic, game theory and philosophy including Artificial Intelligence, Journal of Artificial Intelligence Research (JAIR), Journal of Logic and Computation, Journal of Logic, Language and Information (JOLLI), Studia Logica, Synthese, European Economic Review, Minds & Machines, IJCAI, AAMAS, KR, TARK, AAAI and ECAI. He also authored 23 chapters of books in the fields of AI, logic and philosophy. He is member of the editorial board of the journal “Topoi: An International Review of Philosophy”. He is or has been principal investigator of 4 national projects including the 2012-2014 project EmoTES “Emotions in strategic interaction: theory, experiments, logical and computational studies” funded by Agence Nationale de la Recherche (ANR). He has been leader of the working group “Group attitudes” of the European Network for Social Intelligence (SINTELNET). He has been PC chair of 11th European Workshop on Multi-agent Systems (EUMAS 2013), of the First European Conference on Social Intelligence (ECSI 2014), of the Eighth Workshop on Logical Aspects of Multi-Agent Systems (LAMAS 2015) and of the Second International Workshop on Norms, Actions and Games (NAG 2016). He will be PC chair of the 7th International Conference on Logic, Rationality and Interaction (LORI-VII). Moreover, he has organized 5 international conferences and workshops in the areas of AI, game theory, and logic. Since 2009, he has taught 4 courses and 3 tutorials in international summer schools and conferences: ESSLLI 2009, ESSLLI 2014, EASSS 2011, EASSS 2015, AAMAS 2012, AAMAS 2017, UNILOG 2018. He has been guest editor of five special issues of the Journal of Philosophical Logic, Synthese, Journal of Logic, Language and Information (JOLLI), Journal of Applied Non-Classical Logics (JANCL) and AI & Society. He edited a volume for the series “Studies on the Philosophy of Sociality”, Springer. Since 2009 he has co-supervised 6 Ph.D thesis at IRIT, Université Paul Sabatier.

IRIT (Institut de Recherche en Informatique de Toulouse) team will include other researchers with strong skills and competencies in different areas of AI including logic, planning and argumentation. They will turn out to be particularly useful in the context of WP2 in which the cognitive planning module of the artificial agent will be designed: **Leila AMGOUD** (CNRS research director), **Andreas HERZIG** (CNRS research director), **Dominique LONGIN** (CNRS researcher) and **Frédéric MARIS** (Associate professor).

LIMSI (Laboratoire d’Informatique pour la Mécanique et les Sciences de l’Ingénieur, Paris) team will include researchers with an expertise in both AI cognitive modelling and psychological models of emotions and personality. **Nicolas SABOURET** (Full professor) is a computer scientist whose research focuses on modeling and simulating human behaviour, with a particular interest in social interaction, using logic-based and rule-based modeling approaches. **Céline CLAVEL** (associate professor) is a psychologist whose research work is devoted to study affective processes at stake during social interactions in real or virtual contexts and to design adapted user interfaces. Their interdisciplinary competencies (AI, cognitive sciences and psychology) will be fundamental in the context of WP2 in which the user’s personality dimension will be integrated into the cognitive planning perspective as well as in the context of WP5 about evaluation of the persuasive artificial agent.

LIS-AMU (Laboratoire d’Informatique & Systèmes, Université d’Aix-Marseille) team will include researchers with a long-time expertise in sentiment analysis, automatic corpus analysis and computational models of nonverbal behavior: **Magalie OCHS** (associate professor), **Sébastien FOURNIER** (associate professor), **Adrian-Gabriel CHIFU** (associate professor) and **Patrice BELLOT** (full professor). Such competencies will be fundamental for the project, especially in WP1 and WP3 that will be devoted, respectively, (i) to the collection, annotation and analysis of a corpus of human-human interaction in the context of a persuasive task, and (ii) to the development of a computational model of verbal and nonverbal behavior for the artificial agent.

LPL (Laboratoire Parole & Langage, Aix-en-Provence) team will offer the required expertise on linguistics. This will be particularly relevant in the context of WP1 about collection, annotation and analysis of a corpus of

human-human interaction in the context of a persuasive task. The team includes experts on linguistic models of feedbacks, corpus analysis, nonverbal behavior in H-H conversations: **Noël NGUYEN** (Full professor), **Roxane BERTRAND** (CNRS researcher), **Philippe BLACHE** (CNRS research director) and **Laurent PREVOT** (full professor), **Brigitte Bigi** (CNRS researcher), **Stéphane Rauzy** (CNRS research engineer).

The project consortium also includes **DAVI-The Humanizers** (<http://www.davi.ai>) a private enterprise (SME) with a strong expertise in embodied conversational AI agents design and production. The skills and competencies deployed by DAVI in the project will range from knowledge representation (ontology) to NLP and 3D modeling. The DAVI team includes three members: **Didier BULTIAUW**, **Yannick GERARD** and **Aymeric DAVID**. DAVI will play an important role in the project especially at the level of integration of the different components of the agent architecture (WP4), in the perspective of building a new AI technology aimed at taking care and improving the well-being and health of elderly people.

The project consortium also includes a subcontracting unit, **INSERM - U1093 - CAPS** (Cognition, Action, et Plasticité Sensorimotrice), Université Bourgogne Franche-Comté. This unit will be coordinated by **France MOUREY** (full professor). She is member of the ethical space (“espace éthique”) Bourgogne Franche-Comté and has a long-time expertise in ethical aspects of research projects in the areas of healthcare, gerontology and geriatrics. She is also in contact with several associations of retired people who participated in previous research and development (R&D) activities in which she was involved at Espace Marey, Université Bourgogne Franche-Comté. Thanks to these contacts, she will give access to the targeted population (elderly people) for one of the envisaged case-studies both in WP1 (collection of corpus) and WP5 (evaluation). She will also examine any possible issues regarding ethics emerging during the project and supervise the project to guarantee that the empirical analysis will be conducted in respect of the persons involved in the experiments and in conformity with the ethical standards and legislation.

b. Means of achieving the objectives

This section provides a description of the project workplan structured into six work packages (WPs). For each WP, we mention the partner responsible for it. Figure 1 summarizes the overall structure of the CoPains project highlighting the expected length, the timing of the deliverables for each WP.

		Project month																	
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
WP0 (IRIT)		D 0.1					D0.2						D0.3					D0.4	D0.5
WP1 (LPL)	Task 1.1					D1.1													
	Task 1.2						D1.2												
	Task 1.3													D1.3					
WP2 (IRIT)	Task 2.1												D2.1			D2.2			
	Task 2.2													D2.3			D2.4		
WP3 (LIS)	Task 3.1															D3.1			
	Task 3.2															D3.2			
	Task 3.3																D3.3		
WP4 (DAVI)	Task 4.1										D4.1								
	Task 4.2															D4.2			
	Task 4.3																		D4.3
WP5 (LIMSI)	Task 5.1						D5.1												
	Task 5.2																	D5.2	
	Task 5.3																		D5.3

Figure 2: Project work plan

WP0: Coordination and project management (IRIT)

This WP concerns project coordination, dissemination of results, and valorisation. In order to facilitate coordination of the different partners, a project pilot committee will be created comprising a representative of each partner. Bi-monthly meetings will be called by the project coordinator during which the advancement of the project will be monitored and discussed. Additional issues may be addressed and additional project partners may attend these meetings. In addition, work package meetings between partners will be encouraged in order to address specific issues as needed.

An ethics advisory board composed of representatives of the end-users, scientists and philosophers will be set up in order to discuss ethical aspects of the project. The ethics advisory board will also monitor the project by continuously assessing whether any additional ethical issues or concerns surface throughout the duration of the project. The ethics advisory board will meet once a year. After each meeting of the advisory board, a progress report will be written. In parallel, all experimental protocols will be submitted to a research ethics committee such as “Comité d’évaluation éthique de l’Université Paris-Saclay”.² Finally sufficient means have been allocated to assure the necessary resources in terms of time and budget for the production and publication of scientific papers in national and international conferences and peer reviewed journals. Additional resources are also allocated to the creation and maintenance of a project mailing list, website, and collaborative workspace. Regular updates concerning project advancement and dissemination of publications and public presentations are scheduled.

Deliverables:

- D0.1 (t0+2): Website of the project ready and available in the Internet.
- D0.2 (t0+12): Short report of the first meeting with the ethics advisory board.
- D0.3 (t0+24): Short report of the second meeting with the ethics advisory board.
- D0.4 (t0+34): Short report of the third meeting with the ethics advisory board.
- D0.5 (t0+36): Report describing the activities taken by the consortium to promote the results and technological innovation of the project both at the scientific community level and at the industrial level.

WP1: Collection, annotation and analysis of a corpus of human-human interaction in the context of a persuasive task (LPL)

In this WP, the objectives are first to collect a corpus of interpersonal interaction with elderly people in the scenario studied in the project (Task 1.1); second, to manually and automatically annotate verbal and nonverbal cues of both interactants using existing tools (Rauzy et al., 2014; McDuff *et al.*, 2016) (Task 1.2); and third, to analyze the corpus by combining conversational analysis, automatic requesting and data mining techniques (Chollet *et al.*, 2017; Porhet *et al.*, 2017) (Task 1.3).

Task 1.1. Collection of the corpus (LPL, LIMSI, INSERM). The goal of this task is to constitute a corpus of annotated videos of interaction between two individuals in a professional context. Two case-studies will be considered, in line with the two scenarios briefly illustrated above, namely recommending regular physical activity to an elderly person and giving advices about healthy nutrition lifestyle. The specification of the case-studies and of the corresponding scenarios will be carried out in the context of WP5 (Task 5.1). Each case-study requires a specific corpus with a variety of individuals. Existing corpora will be explored such as (Piperini, 2012). Moreover, these corpora will be completed by a new corpus collected in collaboration with the INSERM partner. In this corpus, one of the interactants is an adviser trying to persuade the interlocutor to change her behaviour so as to improve her health. In the new corpus, personality profiles will be collected following the Regulatory Focus Theory (RFT) using the RFQ-PF scale (Faur *et al.*, 2016). This corpus will be used in the project to 1) collect multimodal expressions (Tasks 1.2, 1.3 and WP3), 2) collect semantic information (WP2) and 3) collect personality profiles (WP2).

² <https://www.universite-paris-saclay.fr/fr/polethis#comite-ethique>

Task 1.2. Annotation of the corpus (LPL, LIS). Analyzing persuasive dialogues between humans requires to highlight on the factors that could contribute to persuasion. The main goal is to identify the evolution of the user's affective states and cognitive attitudes (belief, desire, intention, etc.). We have to determine what are the different verbal and nonverbal parameters associated with each state or attitude, each of them exhibiting a set of multimodal parameters (type of vocabulary, prosody, disfluencies, orientation gaze, attitudes, etc.). In a first step, an annotation phase will be performed in an extensive way. From a basic level of transcription (including disfluencies) all the different levels (prosody, morphosyntax, discursive markers, lexical semantic, backchannels) as well as the nonverbal level (orientation gaze, eyebrows movements, smiles) are performed and aligned on the signal. The annotation of the persuasive sequences will be done by three experts. The manual annotation will be enriched by automatic annotations. For this purpose, three particular tools will be used. First, we will use sentiment analysis models developed by the LIS (Htaït *et al.* 2017) to automatically annotate the *sentiment associated to a sentence* when the data are not numerous. Secondly, we will exploit the openFace system exploited by the LPL to automatically annotated facial expressions (Rauzy & Goujon, 2018). Third, on the basis of the adaptation of learning models developed at the LIS on sentiment-based contradictions (Badache *et al.*, 2017a; Badache *et al.*, 2017b), we will perform automatic annotation of the *opposition and its strength in a dialogue between the two interlocutors*. These annotations will be used to measure the effectiveness of the persuasion.

Task 1.3. Analysis of the corpus (LIS, LPL). Given the type of corpus studied and the cost of the annotation of complex phenomena such as persuasion, we are in a “small data” perspective with the objective to extract knowledge on the different relations between the annotations: modalities, affective states and cognitive attitudes and perceived persuasion. The objective in this task is to apply *machine learning methods* to automatically extract information on the verbal and nonverbal behavioral characteristics of the expressions of persuasion; *i.e.* to link the verbal and nonverbal annotations to the annotation on the perceived persuasiveness. Some recent research works have shown that supervised and unsupervised machine learning methods can be used for data-mining on multimodal, high dimensional, sparse and partial data and with a learning on a small dataset (Forman *et al.*, 2004; Pasini, 2015; Lahat *et al.*, 2015). For instance, we aim at exploring unsupervised machine learning methods to identify hierarchical clustering of modalities and features selection algorithms to analyse the importance of certain multimodal signals in perceived persuasiveness (Ochs *et al.*, 2017). These methods will be combined with specific data-mining methods to explore more fine-grained phenomena and in particular the importance of the sequencing of multimodal signals in the perceived persuasiveness. The objective is to extend the approach, explored recently by LPL and LIS, on sequences mining of multimodal signals triggering feedbacks (Porhet *et al.*, 2017) to analyze the specificity of feedback behavior conveying persuasiveness. One main challenge here is to extract high level knowledge from the multimodal sources by fusing the available signals, while taking into account their interdependency.

Deliverables

- D1.1 (t0+10): Report describing the detailed multimodal coding scheme.
- D1.2 (t0+12): Transcription and annotation of 5 to 10 hours of human-human interactions.
- D1.3 (t0+26): Report illustrating the automatic and manual analysis of the corpus.

WP2: Cognitive planning module (IRIT)

This WP is devoted to the development of the cognitive planning module of the artificial agent. The cognitive planning module will take a persuasive goal as well as the representation of the user's cognitive and affective states in input and will return a persuasion plan in output. This WP is structured in two tasks. The first task (Task 2.1) will be devoted to the theoretical analysis of cognitive planning and to the development of a cognitive planning algorithm to be used in the context of the agent's architecture. The second task (Task 2.2) will be devoted to the enrich the cognitive planning perspective with the personality dimension.

Task 2.1 Cognitive planning: from theory to practice (IRIT). This task is devoted to studying cognitive planning from a theoretical perspective. We will first provide a precise formulation of cognitive planning in

relation to AI classical planning and epistemic planning. In general terms, a *planning problem* can be seen as a tuple $\Sigma = (S, s_0, \alpha, \text{Act})$ which consists of (i) a set S of possible states of the system, (ii) an initial state $s_0 \in S$, (iii) a goal α that can be more or less satisfied in a given state, and (iv) a set Act of possible actions mapping states to states. A solution to the planning problem is a sequence of actions leading from the initial state to a state satisfying the goal. Typical planning problems that will be studied in the context of this task are:

- PLAN – EXISTENCE(Σ): does the planning problem Σ has a solution?
- PLAN – LENGTH(Σ, n): does the planning problem Σ has a solution of length $\leq n$?

In *classical planning*, à la STRIPS or PDDL, the set S includes all models of propositional logic, α is a formula of propositional logic and a solution consists of a sequence of actions leading from the initial model to a model satisfying the goal formula. Complexity of both PLAN – EXISTENCE(Σ) and PLAN – LENGTH(Σ, n) for classical planning is known to be PSPACE (Bylander, 1994). *Epistemic planning* is the generalization of classical planning in which the goal α is about an agent's knowledge or beliefs, *e.g.*, the goal to induce someone to believe something. Epistemic planning has been shown to be decidable in the single-agent case and undecidable in the multi-agent case (Bolander & Andersen, 2011). In the context of this task, we will define *cognitive planning* as the generalization of classical planning and epistemic planning in which the goal α is about an agent's cognitive state. The latter includes not only knowledge and beliefs but also intentions. For example, in cognitive planning, α may correspond to the goal to induce someone to have a certain intention and to behave in a certain way. We will provide a formal specification of a cognitive planning problem in a logic developed by the IRIT participants and based on their previous work on the logical formalization of cognitive attitudes and emotions and on epistemic planning (Lorini, 2011; Dastani & Lorini, 2012; Adam *et al.*, 2009; Cooper *et al.*, 2016). We will study the computational complexity of the cognitive planning problem formulated in the logic and develop a cognitive planning algorithm to be implemented in the agent architecture depicted in Figure 1 and to be integrated in the DAVI platform (see Task 4.3 of WP4 for more details).

Task 2.2 Personalization and adaptation in argumentation (LIMSI, IRIT). This task will consist in enriching the cognitive planning perspective of Task 2.1 with the personality dimension. Specifically, we will specify high-level rules to be used in the context of the agent's architecture depicted in Figure 1. These rules will implement argumentation strategies aimed at persuading the interlocutor depending on her personality traits. This work will be based on the model defined by (Faur *et al.*, 2015). It combines symbolic AI methods, based on expert rules, with machine learning methods to build a decision tree that encode behaviour rules. The Ph.D student hired at LIMSI will thus be in charge of defining the articulation between theoretical models from psychology, the analysis of the corpus in terms of persuasive behaviour conducted in WP1 and the implementation of these two aspects in a computer science model. The system will be capable of detecting the user personality profile using a Theory of Mind (ToM) approach to evaluate the behaviour of the interlocutor based on the theoretical model of behaviour (see OuldOuali *et al.*, 2018). LIMSI and IRIT will work in collaboration in the context of this task in order to integrate the high-level rules for persuasive argumentation into the logic-based approach to cognitive planning developed in Task 2.1.

Deliverables:

- D2.1 (t0+24): Report presenting the theoretical study of cognitive planning.
- D2.2 (t0+30): Report describing the cognitive planning algorithm.
- D2.3 (t0+26): Report describing the model of adaptation and personalization in argumentation.
- D2.4 (t0+32): Report describing the integration of the high-level rules for persuasive argumentation into the logic-based approach to cognitive planning.

WP3: Computational model of verbal and nonverbal behavior (LIS)

The objective of this WP is to give to the artificial agent the capacity to reason on the appropriate behavior, both verbal and nonverbal, that should be expressed during the interaction in order to be persuasive. It is

structured in three tasks. The first task focuses on the listening behavior of the artificial agent and more precisely on the development of a computational model of feedbacks to reason on the most appropriate verbal and nonverbal signals that the artificial agent should display when it is listening in order to be persuasive. Tasks 3.2 and 3.3 focus on the behavior of the artificial agent when it is speaking. Task 3.2 tackles the nonverbal part, whereas Task 3.3 focuses on the verbal part and on the synchronisation of the verbal production with the nonverbal behavior of the artificial agent.

Task 3.1 Computational model of feedbacks (LIS, LPL). This task tackles the problem of the feedback behavior of the artificial agent (the backchannel in Figure 1). The feedbacks can be both verbal and nonverbal, and play a key roles in an interaction with an artificial agent (*e.g.*, perception of the agent, flow of the conversation, establishment of the relationship) (Gratch *et al.*, 2006). The analysis of the corpus conducted in WP1 (Task 1.3) will be used to develop a computational model of feedbacks integrating the rules on the types of feedbacks triggered depending on the course of the conversation. To construct a feedback model integrating multimodal signals exchanged during an interaction requires choosing the appropriate representation to consider the different characteristics of multimodal signals. We expect to use a *stochastic* model to reflect the non-deterministic aspect of signals. Moreover, to model the *causal relations* (for instance between the signals of the two interactants) as well as the *temporal relations* (duration of the signals and the temporal sequences) Markov models such as *dynamic Bayesian networks* (DBNs) will be explored.

Task 3.2 Computational model of nonverbal behavior (LIS, DAVI) : The objective in this task is to develop a computational model to automatically compute the nonverbal behavior that the artificial agent should express to be persuasive when it is speaking. Rules will be defined by combining an empirical approach (the results of the corpus analysis in WP1) and a theoretical approach based on an extensive literature review on human persuasiveness (Cesario & Higgins, 2008). Different parameters of the nonverbal behavior will be considered: the type of the gesture or facial expressions (*e.g.*, expressions of joy, pointing gestures) but also the morphological and dynamic characteristics (duration, amplitude, openness of the mouth, etc.). Moreover, in a multimodal perspective, attention will be paid to the synchronisation of the nonverbal behavior and the verbal message (*e.g.*, a smile could not have the same impact at the end, at the beginning or during an utterance).

Task 3.3 Dialogue strategy (LIMSI, IRIT, DAVI). This task aims to develop a computational model that takes the abstract plan generated by the cognitive planning module developed in WP2 as input and returns a sequence of dialogue utterances as output. The model will take into account the user profile acquired through the interaction (based on the corpus collected in WP1) and social dialogue rules designed at LIMSI (Ouldouali *et al.*, 2017). In Task 4.3 of WP4, the computational model will be coupled with a module for text generation based on the DAVI NLG engine and the nonverbal behavior engine.

Deliverables:

- D3.1 (t0+30): Report presenting the the computational model of feedbacks.
- D3.2 (t0+30): Report presenting the computational model of nonverbal behavior.
- D3.3 (t0+32): Report presenting the computational model for the dialogue strategy.

WP4: Integration (DAVI)

The objective of this WP is to integrate the result of the others WPs into the DAVI system, the RETORIK platform. The RETORIK platform includes a set of services for embodied conversational agents (ECAs). The services used in the context of the CoPains project are: (i) NLP service including a NLU part (modules LOGOS and MEMORIA) and a NLG part (modules RIPOSTA and ACTIO), and (ii) an animation engine based on dynamic scenarios. The functions of the NLP service are: - the lemmatization module LOGOS, - the ontology MEMORIA, to understand the meaning of a sentence in the expert domain, - the behavioral module RIPOSTA, to manage the dialog strategy, and - the output module ACTIO to generate a human readable answer. This WP is structured in the three tasks which consists in, respectively:

- connecting a nonverbal recognition module to the NLP system (Task 4.1),

- creating an ontology for verbal recognition in the MEMORIA module (Task 4.2), and
- adapting RIPOSTA to the animation engine (Task 4.3).

Task 4.1: *Integration of nonverbal behavior recognition module into RETORIK* (DAVI).

This is a purely engineering task whose aim is to connect the Affectiva emotion detection engine (McDuff *et al.*, 2016) to the input of the NLP module of the RETORIK platform. Affectiva allows to detect the emotions of the user from her nonverbal behaviors and expressions. The combination of the NLP module of RETORIK and Affectiva will provide the basis for a multimodal emotion recognition module allowing to extract a simplified representation of the user's emotions from her verbal behavior and nonverbal behaviors and expressions (*e.g.*, head movements, facial expressions).

Task 4.2: *Configuration of the ontology* (DAVI, IRIT).

This task consists in extending the ontology MEMORIA present in the RETORIK platform with a “background theory” for cognitive attitude recognition. The “background theory” will include a set of rules allowing to infer the user's cognitive attitudes (*e.g.*, beliefs, desires, intentions) from her expressed emotions. A major challenge of this task will consist in linking the representation of the user's emotions extracted via the multimodal emotion recognition module (Task 4.1) with the representation of the user's cognitive attitudes used in the cognitive planning module of WP2. Specifically, the “background theory” will include a set of rules allowing to infer what the user believes, desires, intends, etc. from the emotion she has expressed and has been recognized. Such rules will be specified in conformity with the logical theory of the cognitive structure of emotions by IRIT used in the context of WP2 (Lorini, 2011; Dastani & Lorini, 2012).

Task 4.3: *Integration of the cognitive planning module into RETORIK* (DAVI, IRIT, LIMSI, LIS).

This task consists in integrating the cognitive planning algorithm developed in Task 2.1 of WP2 into the RETORIK system by DAVI in order to endow the artificial agent with the capacity to automatically generate a plan aimed at persuading the human user to believe something or to behave in a certain way. We will combine the cognitive planning module with the recognition module developed in Task 4.1. First of all, we will adapt the strategy dialog module RIPOSTA to the information provided by the cognitive planning module. RIPOSTA will send this information to the animation engine in order to adapt the multimodal behavior of the agent. The animation engine will be configured in conformity with the computational model of feedbacks and nonverbal behavior developed in the context of WP3. The consortium will also study the possibility to exploit the Furhat robotic head (<https://www.furhatrobotics.com/>) in order to take into account the impact of the agent's physical presence on its degree of persuasiveness.

Deliverables:

- D4.1 (t0+20): Report describing the integration of the nonverbal behavior recognition module into the RETORIK platform.
- D4.2 (t0+30): Report describing the extension of the RETORIK ontology by the “background theory”.
- D4.3 (t0+36): Report describing the integration of the cognitive planning module into the RETORIK platform.

WP5: Evaluation of the persuasive artificial agent (LIMSI)

This WP is devoted to the evaluation of the system whose architecture is represented in Figure 1. We will use an iterative approach and a method mixture consisting, *e.g.*, of self-confrontation interviews, questionnaires, log file analysis, video analysis, and measures collected within controlled empirical studies. It is structured into three tasks.

Task 5.1 *Specification of case-studies and evaluation plans for the artificial agent* (LIMSI). This task will be devoted to specify the case-studies about interaction between a human user and an artificial agent, in line with the scenarios presented at the beginning of this document. They will about artificial assistants and

companions for elderly people and for nutrition counselling. As we have explained above, the corpus collected in WP1 will focus on these case-studies.

This task will be conducted primarily during the first six months of the project, in close collaboration with the INSERM partner as representative of the end users. The case-studies will be detailed, including a specification and analysis of the involved users and stakeholders as well as their potential interests. The user requirements will be elicited using different methods, including interviews, think-aloud studies, or observational studies. The result will be a specification of users in different contexts and their potential activities and goals. Based on this specification, a corresponding plan for formative and summative evaluation in the scenarios of the case-studies will be derived (see Tasks 5.2 and 5.3).

Task 5.2 Perception of artificial agent's verbal and nonverbal behavior (LIMSI, LIS, LPL). The aim of this task is to evaluate to what extent the verbal and nonverbal behaviors of the artificial agent are correctly perceived by the user. We propose an experimental study to validate verbal and nonverbal behavior associated to persuasion. The goal is to determine whether endowing the artificial agent with specific nonverbal cues increases its persuasiveness, as suggested by Cesario & Higgins (2008) for human behavior. We will ground our study on regulatory-fit theory to answer this question. We hypothesize that when there is fit between a participant's orientation toward the message and the source's nonverbal style, the participant will "feel right" and the message will be more effective. As suggested by Wang & Lee (2006), participant's orientation can be induced by different techniques (Higgins *et al.*, 1994). Thus, we shall compare three experimental groups (a group for which we shall induce the promotion regulatory focus, a group for which we shall induce the prevention regulatory focus and a control group for which there will be no induction). We hypothesize that when there is fit between an induced regulatory focus and the (verbal or nonverbal) message, the participant will assess artificial agent as more persuasive. These results will allow us to validate the generated verbal and nonverbal expressions. A multimodal approach will be used in order to validate each modality and to evaluate the impact of the combination of the different modalities.

Task 5.3 Evaluation of artificial agent's persuasiveness (LIMSI, IRIT, LIS, LPL). The aim of this task is to evaluate to what extent the artificial agent is persuasive (i.e., capable of changing the user's attitudes and behaviors) and how much this depends on the system customization to the user. An experimental comparative approach will be used. Specifically, we will verify whether participants interacting with an artificial agent endowed with persuasive capabilities will change more their attitudes and behaviors than participants interacting with an artificial agent not endowed with persuasive capabilities.

Deliverables:

- D5.1 (t0+12): Report illustrating two scenarios for the final design of the prototype and for the evaluation of the artificial agent.
- D5.2 (t0+34): Report describing the results of the evaluation of the perception of the agent's behaviour.
- D5.3 (t0+36): Report describing the results of the evaluation of the agent's persuasiveness.

Requested means

The distribution of the requested funding for the CoPains project is summarized in the following table.

Partner	Staff expenses	Travel costs	Instruments and material costs	Administrative Management costs	Provision of services	Subtotal
IRIT	100 160 €	20 800 €	4000 €	14 732 €	50 000 €	188 957 €
LIMSI	110 300 €	10 000 €	2000 €	9784 €	0 €	132 084 €
LIS	55 080 €	8000 €	2000 €	5206 €	0 €	70 286 €
LPL	64 260 €	13 000 €	5000 €	7212 €	7900 €	97 372 €
DAVI	97 000 €	8000 €	0 €	19 400 €	0 €	55 980 € (45%)
						Total requested: 544 680 €

Total requested grant is 544 680 €. **Staff expenses** include:

- IRIT: salary for one Ph.D student for IRIT (100 160 €) working in the context of WP2,
- LIMSI: salaries for one Ph.D student and four student trainees for LIMSI (98 100 € + 12 200 €) working in the context of WP2, WP3 and WP5,
- LPL and LSIS: salaries for 14-month postdoc for LPL (64 260 €) and 12-month postdoc for LSIS (55 080 €) working, respectively, in the context of WP1 and WP3, and
- DAVI: salary for the R&D cell for DAVI (97 000 €) working in the context of WP4.

The four student trainees for LIMSI will work, respectively, on the annotation of corpus in terms of behaviors based on personality traits, on the evaluation of persuasiveness of argumentation, on the evaluation of nonverbal behaviors for persuasion, and on the evaluation of the model of personality.

Travel costs correspond to costs for dissemination of results at national and international conferences and for participation in regular meetings with the other project partners to be organized in Toulouse, Paris, Marseille or Nivers. Our calculation is based on the estimation of approximately 2000 € per person for participation in an international conference, approximately 800 € per person for participation in a national conference and approximately 500 € per person for participation in an external project meeting, *i.e.*, a project meeting whose attendance requires a work trip and a hotel accommodation. This includes:

- IRIT: 6 participations in international conferences, 6 participations in national conferences and 8 participations in external project meetings for the three years of the project to be distributed among the six members of the team (Ph.D included),
- LIMSI: 3 participations in international conferences, 2 participations in national conferences and 5 participations in external project meetings for the three years of the project to be distributed among the three members of the team (Ph.D included),
- LIS: 2 participations in international conferences, 2 participations in national conferences and 5 participations in external project meetings,
- LPL: 4 participations in international conferences, 3 participations in national conferences and 5 participations in external project meetings for the three years of the project, and
- DAVI: 1 participation in an international conference, 3 participations in national conferences and 7 participations in external project meetings.

We also include **instruments and material costs** for equipping the Ph.D students, the postdocs and one or two members of each team with a laptop or a workstation. Our calculation is based on the estimation of approximately 1000 € for a laptop and 2000 € for a workstation. This includes: IRIT: 2 workstations, LIMSI: 2 laptops, LIS: 2 laptops, LPL: 2 workstations and 1 laptop.

As for **provision of services** for IRIT (50 000 €), this includes the costs related to the activities of subcontracting unit PU INSERM - U1093 “Cognition, Action, et Plasticité Sensorimotrice”, Université Bourgogne Franche-Comté. This includes the expertise of France Mourey on examining any possible issues regarding ethics emerging during the project and on supervising the project to guarantee that the empirical analysis of WP5 will be conducted in respect of the persons involved in the experiments and in conformity with the ethical standards and legislation. As emphasized above, France Mourey is member of the ethical space (“espace éthique”) Bourgogne Franche-Comté and has a long-time expertise in ethical aspects of research projects in the areas of healthcare, gerontology and geriatrics. France Mourey is also in contact with several associations of retired people who participated in previous research and development (R&D) activities in which she was involved at Espace Marey, Université Bourgogne Franche-Comté. Thanks to these contacts, she will give access to the targeted population (elderly people) both for the evaluation part (WP5) and for the collection of corpus (WP1). Subcontracting costs for INSERM also includes the salary of an engineer working in collaboration with France Mourey and the other members of the project. The engineer will (i) constantly update the database containing information about people to be contacted for the experiments (*e.g.*, mail addresses, phone numbers, etc.), and (ii) help to build the methodology for evaluation, to process the data

obtained during evaluation, to write scientific articles related to WP1 and WP5. We also include 7900 € for LPL that will be needed to use the experimental platform “Centre d’Expérimentation sur la Parole” (CEP) (<https://recherche.univ-amu.fr/fr/plateforme>) for the collection and annotation of corpora at Université Aix-Marseille. The paiement for the use of this service will be made through the intermediary Protisvalor (<http://www.protisvalor.com/site/fr>).

III. Impact and benefits of the project

CoPains is clearly at the core of the ANR 2018 call “Défi 7, Axe 3 : Interaction, Robotique - Intelligence Artificielle” given its strong emphasis on the multimodal and cognitive aspects of HMI and the central role played by AI in the project. Our consortium will take a great care on ethical aspects of HMI, with the help of ethical boards in our institutions, given its focus on persuasive technologies.

The project is expected to have a strong impact both at theoretical level and at the practical level. The main ambition of the project is to combine different methodologies from different areas of AI in order to develop a computational system that is, at the same time, theoretically founded, empirically validated and exploitable in practice. More generally, the strength of the CoPains project lies in the combination of a formal methodology with an empirical approach. As far as we know, CoPains is the first national project on human-machine interaction that tries to combine the *mathematical rigor* derived from the use of formal methods from AI with the *empirical adequacy* and *practical usability* derived from the use of methods from corpus-based analysis for social signal processing and data-mining. At the scientific level, we expect the results of the project to be published in top conferences in the area of artificial intelligence and affective computing such as IJCAI, AAMAS, ECAI, AAAI, IVA, ACII, JAAMAS, IEEE TAC, ACM TIIS.

According to the World Health Organisation (WHO), sedentary lifestyle is a major cause of preventable death in the world today, a risk factor for physiological, psychological and social problems (cardiovascular diseases, overweight/obesity, stress, depression, social isolation, and development of major chronic illnesses) and for the reduction of life expectancy. One of the goals of the member states of the WHO is to reduce the sedentary lifestyle both of young people and of senior individuals. The objective of our project is develop a new AI technology aimed at encouraging and promoting physical activity and healthy dietary behavior. User studies will be conducted during the project. Indeed, in order to meet users’ expectations, it is necessary to introduce user feedback in the design of the technology and to carry out regular evaluations of it. The presence of the INSERM subcontracting unit in the consortium guarantees that we will have access to the targeted population of end users for one of the envisaged case-studies, namely the elderly. If the artificial agent prototype developed in the project is successful in promoting healthy behavior, we will have achieved a significant result with a strong impact in the domain of assistive devices.

At the industrial level, we expect to propose a new kind of AI services dedicated to the well-being and health of people both in public institutions and in domestic environments. Today’s chatbots provide “cold services” useful for business purposes (sale, self-care, etc.), but they drastically lack emotion management and are completely unable to take into account the user’s beliefs, desires, needs, preferences, etc. This is a strong limitation especially for a technological solution that is expected to promote the wellbeing of an elderly person and to take care of her health. The CoPains project is aimed to fill this gap by developing a persuasive artificial agent with the capacity to understand the cognitive attitudes and affective states of a human. It will be a companion that will take care of the user across a broad spectrum of situations. It will be a revolutionary system adapted to our evolutive technology world, our population repartition and life-span. DAVI expects an improvement for its IA platform at the NLG level, with a challenging integration of several modalities from different sources to provide an adapted and dynamic response, and new possibilities for its 3D modeling.

The project CoPains will build a new kind of human-machine interface, autonomous and persuasive. DAVI intends to commercialize it as a tablet. Two use cases are envisaged corresponding to the two scenarios illustrated at the beginning of the document. The first one is about an artificial companion taking care of an elderly person in her day-to-day-life at home (physical activities, medication, warning, communication with family/friends, house management, appointment management, etc.). The artificial agent will be coupled with a

monitoring system for health professionals in order to anticipate psychological difficulties due to exclusion, solitude and dependency. The second case-study is about nutrition: a virtual agent helping a person to adopt a healthy nutrition lifestyle and to meet her dietary requirements. In this promising framework, DAVI expect concerning the sales 150k€ one year after the end of the project (2022), 600k€ in 2023 and 1,5M€ in 2024.

IV. References related to the project

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