

The hidden path from delegation to obligations: a logical analysis

Emiliano Lorini¹

Abstract. Delegation is one of the main determinants of coordination, joint activity and collaboration within the context of organizations. In particular, delegation is fundamental for the redistribution and for the transfer of tasks within the context of an organization, and is responsible for making organizations dynamic. We present in this paper a conceptual and formal analysis of delegation. In our approach, delegation is a kind of social action that involves two agents called the delegant and the delegate, that the delegant performs by giving an order to the delegate, and that produces certain normative effects on the delegate and, in particular, an obligation for the delegate to perform the delegated task. The concept of delegation and its essential conditions will be formalized by a modal logic of agents' mental attitudes including beliefs and goals, extended by communication modalities which enable to describe what a given agent tells to another agent in front of a group of agents (an audience).

1 Introduction

When looking at social interaction within the context of organizations, social scientists have been mostly interested in individuating the antecedents of collective behavior and collective action between interacting individuals. A central concern of the field has been to identify the determinants and constituents of coordination, joint activity and collaboration. Among the different determinants, trust and delegation have been recognized as ones of the most important [2, 22, 6].

The primary function of delegation is the redistribution and the transfer of tasks, powers, and obligations, within the context of an organization. Suppose that agent i is the chief of an organization and has a general goal to achieve. Moreover i has authority over other members of the organization called agent j and agent z . Agent i might decide to exploit agent j and agent z in order to achieve his goal thereby forming a complex plan involving the actions of j and z . In this situation, i will delegate some elements in his multi-agent plan to j and z and, as an effect of the delegation act, there will be an *obligation directed to j and z* to accomplish the tasks required by i .² In this situation, i 's act of delegation to j and z is an exercise of authority by agent i over his subordinates j and z whose effect is the creation of certain obligations over j and z . Note that i 's authority over j and z (i 's right to require j and z to perform certain actions and to accomplish certain tasks) is nothing else than a specific kind of *institutional power* of agent i .

The aim of our work is to clarify the concept of delegation which is of primary importance not only for organization theory and for the design of agent organizations, but also for the design of multi-agent applications in which agents are very specialized and some of them have heavy workloads. In these situations, an agent could delegate certain tasks to other agents in order to optimize his performance and the performance of the whole system.

We provide a formal cognitive analysis of delegation by modeling interacting agents in terms of their mental attitudes (beliefs, goals, intentions) and in terms of their communicative actions. On the one hand, we define the essential *mental constituents* of delegation, that is, those mental attitudes which characterize the cognitive state of an agent delegating the performance of a certain action (or task) to another agent. On the other hand, we describe the overt social level of delegation by specifying what an agent *expresses* when he delegates the performance of a certain action (or task) to another agent.

The analysis of the delegation proposed in this work is compatible with Speech Act theory [20, 24]. Indeed, we claim that delegation requires a communicative process from the delegant to the delegate. More precisely, we claim that delegation is a kind of social action that involves two agents called the delegant and the delegate, that the delegant performs by giving an order to the delegate, and that produces certain normative effects on the delegate and, in particular, an obligation for the delegate to perform the delegated task. This relationship between delegation and obligations will be in the focus of the present analysis. We will shed light on the hidden path from delegation to obligations, by showing that agent i 's act of delegating action α to agent j necessarily gives rise to an obligation for j to do the delegated action, because a necessary precondition of i 's act of delegating action α to j is i 's power to command j to do action α .

The sequel of the article is organized as follows. In Section 2 we provide an informal analysis of delegation trying to individuate its essential constituents. This part of the work provides the conceptual backbone of all the work. In Section 3, we present a formalism which is sufficiently expressive to capture the concept of delegation discussed in Section 2. It is a modal logic of agents' mental attitudes including beliefs and goals, extended by communication modalities which enable to describe what a given agent tells to another agent in front of a group of agents (an audience). In Section 4 the modal logic of Section 3 will be used in order to define the concept of delegation, and to shed light on the logical relationship between delegation and obligations. In Section 5 we will discuss some related works on the concept of delegation.

¹ Université de Toulouse, IRIT-CNRS, France, email: lorini@irit.fr

² In the present analysis, when we talk about the concept of obligation, we just refer to the specific concept of *directed obligation* (see, e.g., [7, 14] for a general account of the concept of directed obligation): obligations which are directed from the delegate (responsible for fulfilling the obligation) to the delegant.

2 Delegation: an informal view

We conceive delegation as a specific kind of a social action involving two agents, the delegant and the delegate.

In our approach, an act of delegation is performed if and only if, the delegant orders the delegate to accomplish a certain task or to do a certain action α and the delegant has the power to command the delegate to do α . Therefore, in order to understand what *delegation* is, we have to define first the concept of *order*. The analysis of order and the related concept of request we propose is compatible with Speech Act theory.

The primary aim of Speech Act theory [20, 24] is to identify the *conditions of success* of a communicative act (or speech act)³, that is, the conditions that must be obtained in a possible context of utterance in order that the speaker successfully performs that act in that context. For example, a condition of a promise to perform a certain action in a certain context is that the speaker intends to perform this action in this context (sincerity condition). If the speaker does not intend to perform this action in this context, then he cannot make a (non-defective) promise to perform this action in this context.⁴

Let us now explain what are the different conditions that must be satisfied in order to say that a certain speaker called i has performed an order. First of all, we have to suppose that agent i has a goal to achieve and that i decides to exploit an action α of another agent j in order to achieve such a goal. In this case, agent i *relies* on action α of agent j , what is exactly described by the following Condition A:

(A) agent i wants (or intends) that agent j will perform action α .

This aspect of *reliance* is for us the first necessary constituent of directive speech acts including requests and orders, where reliance just means an agent's decision to exploit the actions of other agents in order to achieve his goals.

Rational goals and intentions must be realist [4], that is, a rational agent i cannot want something to be true unless i thinks it to be possible. Thus, Condition A implies the additional condition:

(B) agent i believes that agent j has the ability to perform action α .

Reliance is not yet sufficient to define orders and requests, although it is a fundamental dimension of directive speech acts. For instance, suppose that everyday agent i carries a pack of letters to the post office. If agent j adds a letter to the pack of letters without i seeing j , j relies on i but we cannot say that j makes a request (or gives an order) to i . Orders and requests imply a communicative dimension that it is not necessarily implied by reliance. Indeed, if an agent i orders an agent j the performance of a certain action α then, necessarily:

(C) i tells to j that Condition A is true (i.e. that he wants that j will perform action α).

³ Roughly speaking, 'speech acts' and 'communicative acts' are the same thing. Speech Act theory is indeed sufficiently general to speak about communication in general (verbal communication, communication by gestures, by facial expressions, etc.). The main objective of Speech Act theory is indeed the specification of different *types* of acts with different illocutionary forces (request, order, promise, etc.), independently from how every instance of speech act is really realized and performed.

⁴ Technically in Speech Act theory, if this condition is *expressed* through the performance of this act, this performance will be successful. Moreover if the speaker is here sincere (that is, he believes what he expresses) the performance of this act will be non defective. See [24, p. 130] for more details. Here, we do not distinguish between success conditions and non-defective conditions.

As emphasized by Vanderveken [24] sincerity conditions are necessarily *expressed* by the speaker when a speech act of directive type is performed. Conditions A and B are respectively nothing else than the sincerity condition and a preparatory condition of directive speech acts. Thus, Condition C just says that order entails the speaker's expression of the sincerity condition of a directive speech act.

It has to be noted that Conditions A and B above are *external (or overt) conditions* since they are about the open and objective level of communication (i.e. they are characterized in terms of what the speaker expresses), and are distinguished from *internal (or mental) condition* C which refers to the subjective level of communication (i.e. it is characterized in terms of the speaker's mental states). It has also to be noted that Conditions A, B and C together define the basic directive speech act *request* (see the first row in Fig. 1).

	Mental (sincerity condition)	Mental (preparatory condition)	External	Power to command
Request	A	B	C	/
Order	A	B,D	C,E	/
Delegation	A	B,D	C,E	F

Figure 1. Conditions of request, order and delegation

In order to define the concept of order, other conditions have to be added. Order has a normative dimension which is not necessarily a dimension of request. In particular, if agent i orders agent j the performance of action α then, necessarily:

(D) agent i believes that he has the power and the authority to command agent j to do action α .

Moreover, if agent i orders agent j the performance of action α then, necessarily:

(E) i tells to j that if j does not perform action α , j will violate a norm and will be liable to punishment.

Again, note that Condition E above is an *external condition* since it is characterized in terms of what the speaker expresses in the context of the communication with j . On the contrary, Condition D is a *mental condition* since it refers to the subjective level of communication (i.e. it is characterized in terms of the speaker's mental states).

Conditions A, B, C, D and E are together sufficient to define the speech act *order* (see the second row in Fig. 1).⁵

We claim here that in order to define delegation it is sufficient to add a new condition to Conditions A, B, C, D and E. Indeed, what really matters in delegation is that i has the power and the authority to command agent j to perform action α , and not simply that i believes that he has such a power. In other words, we claim here that delegation is an order by the speaker which is performed under the appropriate execution conditions (i.e. when the speaker has indeed the power and the authority to give the order). So, if agent i delegates to agent j the performance of action α then, necessarily:

(F) i has the power and the authority to command agent j to do action α .

⁵ Note that orders have also a declarative aspect: when agent i orders agent j to do action α , i declares that j has the obligation to do action α . And, if i has the power and the authority to command j to do action α then, by means of his declaration, i will create the obligation for j to do action α .

From this perspective, delegation is something more than a speech act (see the third row in Fig. 1). It is a speech act of type *order*, as defined by the Conditions A-E, which produces certain normative effects on the hearer, given the speaker's power and authority to command j to do a certain action (Condition F).

The following example better illustrates the six conditions A-F defining delegation.

Scenario 1 Suppose that agent i is the president of a company and suppose that this company must be represented at a journalist meeting. Suppose now that agent i delegates to agent j , an employee of the company, the task of participating to this meeting. In this case, the employee does have any refusal option (this is an order of the president). This means that i relies on j 's action of participating to the meeting (i.e. i wants that j will participate to the meeting) and believes that j is able to participate to the meeting. Agent i also believes that he has the power and the authority to command j to participate to the meeting. Furthermore, i openly tells to j that i wants that j will participate to the meeting and that if j does not participate to the meeting, j will violate a norm and will be liable to punishment. Finally, qua president of the company, i has the power and the authority to command j to participate to the meeting. This is the reason why, after i 's act of delegation, j will be obliged to participate to the meeting.

Note that in the previous scenario, the Conditions D and E allow to distinguish order from a simple request. Moreover, F is the condition that guarantees that the speaker's act will produce normative effects on the hearer. For instance, suppose that agent z is another employee of the company. Again, j has been instructed by the president of the company to participate to the journalist meeting. But j has no wish to do this and decides to ask his colleague z a favour. Agent j does not have the power and authority to command z to participate to the meeting. Thus, agent j cannot order z to participate to the meeting and cannot delegate to z this task. At the most j can make a simple request to z to participate to the meeting instead of him.

Note also that the previous scenario mentions the concept of *representation*, whereby an agent j (the representative) can act in the name of another agent i (the principal), that is, j has the power to represent i at the journalist meeting (see, e.g., [11] for an account of the concept of representation in legal theory). In the scenario, representation is obtained by means of the delegation act by i . Moreover, note that the act of delegation can be conceived as a *mandate* whose effect is the creation of the obligation for j of exercising the power of representation. We postpone to future work an analysis of the relations between our notions of delegation, and the notions of representation and mandate.

Before concluding, let us observe that in certain situations one would like to call delegation an action of agent i directed to agent j even though i (the speaker) did not tell explicitly to j (the hearer) that if j does not perform action α , j will violate a norm and will be liable to punishment. We call *implicit delegation* this weaker form of delegation. In implicit delegation, i wants that j does action α , and has the power and the authority to command j to do α (and believes this). Moreover, i asks j to do α (by telling to j that i wants that j does α) but i does not explicitly reveal to j that i 's request will have certain normative effects on j (i.e. will oblige j to do action α). In other words, in implicit delegation, the speaker performs a simple request to someone knowing that by making the request the other will be obliged to perform the required action. For example, the president of a company may delegate a certain task to his secretary in a very polite way ('Could you please fix the appointment for me?'), with-

out explicitly ordering her to accomplish the task, but knowing that after the request the secretary will be obliged to accomplish the task (given that the president has the power and the authority to oblige the secretary to accomplish the task by asking her to do so). In the rest of analysis we will leave aside this concept of implicit delegation, and we will consider the concept of delegation in a full sense.

The rest of the paper is organized as follows. In Section 3 we introduce a modal logic of mental states, action and communication. The interesting aspect of this logic is that it allows to describe what an agent expresses in the context of conversation and to characterize the social dimension of communication (not simply its mental dimension). It has long been argued that multi-agent systems should have a social semantics (see e.g. [23, 25]), that is a semantics about externally observable objects (such as commitment, permissions, obligations, etc.) rather than about agents' internal mental states (beliefs, intentions, goals, etc.). Our point of view here is that observable states of affairs involved in communication are nothing else than the open and public expressions of internal mental states of the speaker. The logic presented in the next section will enable capture this aspect of communication in a proper way. In Section 4 the modal logic of Section 3 will be first used in order to define the concept of obligation. Then, it will be used to define request and order and, finally, the concept of delegation. In the logical definitions of request and order we will just consider the external (overt) conditions of speech acts (Conditions C and E above). Indeed, these are the most interesting conditions when looking at the social level of communication (e.g. how a speech act affects the social world by helping to achieve coordination, by creating obligations, and so on). Finally, we will shed light on the logical relationship between delegation and obligation, that is, we will explain why a delegation act of i directed to j can create an obligation for j to perform the action delegated by i .

3 A modal logic of mental states, action and communication

We present in this section a modal logic of agents' mental attitudes including beliefs and goals, extended by communication modalities which enable to describe what a given agent tells to another agent in front of a group of agents (an audience). In order to be able to reason about actions of agents and about speech acts of directive type like requests and orders, we include in our logic special atomic propositions denoting action occurrences.

3.1 Syntax

Assume a finite set $AGT = \{1, \dots, n\}$ of labels denoting agents, a countable set $FACT = \{p, q, \dots\}$ of atomic formulae denoting facts, and a countable set of atomic formulae denoting action occurrences $ACT = \{\alpha_1, \beta_1, \dots, \alpha_2, \beta_2, \dots, \alpha_n, \beta_n\}$. For example, if α_1 is true then it means that agent 1 performs action α , if β_2 is true then it means that agent 2 performs action β , and so on. We define $ATM = FACT \cup ACT$. Moreover, we define $2^{AGT*} = 2^{AGT} \setminus \emptyset$ the set of all non-empty sets of agents.

The language $\mathcal{L}$ of the logic $\mathbf{L}$ is the set of formulas defined by the following BNF:

$$\varphi ::= p \mid \neg\varphi \mid \varphi \wedge \varphi \mid \mathbf{Bel}_i\varphi \mid \mathbf{Goal}_i\varphi \mid \mathbf{Tell}_{i,j,C}\varphi \mid \mathbf{X}\varphi$$

where p ranges over ATM , i ranges over AGT and C ranges over 2^{AGT*} . The other Boolean constructions $\top$, $\perp$, $\vee$, $\rightarrow$ and $\leftrightarrow$ are defined from $\neg$ and $\wedge$ in the standard way.

Modalities Bel_i and Goal_i are standard doxastic modalities and standard modalities for goals [5]. The formula $\text{Bel}_i\varphi$ has the following reading ‘agent i believes that φ ’, whereas $\text{Goal}_i\varphi$ has to be read ‘agent i has the goal that φ ’.

Modalities $\text{Tell}_{i,j,C}$ are used to describe what an agent told to another agent in the presence of a group of agents. We read $\text{Tell}_{i,j,C}\varphi$ as ‘agent i told to agent j that φ in the presence of the agents in C ’ or ‘agent i told to agent j that φ in front of group C ’. Given a formula $\text{Tell}_{i,j,C}\varphi$, we call i the *speaker*, j the *addressee*, C the *audience* and φ the *content* of the speaker’s expression (utterance). For example, formula $\text{Tell}_{i_1,i_2,C_1} \text{It is sunny!}$ has to be read ‘agent i_1 told to agent i_2 that it is sunny in front of group C_1 ’. When the speaker and the addressee are the same agent, the expression $\text{Tell}_{i,i,C}\varphi$ refers to a solitary speech of agent i (a monologue).

Finally, the temporal operator $\mathbf{X}$ is the standard *next* operator of linear temporal logic [8]. Formula $\mathbf{X}\varphi$ means ‘ φ will be true in the next state’. The following abbreviation defines the concept of achievement goal in a way similar to [5]:

$$\mathbf{AGoal}_i\varphi \stackrel{\text{def}}{=} \mathbf{Goal}_i\mathbf{X}\varphi \wedge \text{Bel}_i\neg\varphi$$

An agent i has the achievement goal that φ (noted $\mathbf{AGoal}_i\varphi$) if and only if i has the goal that φ will be true in the next state and believes that φ is currently false. Formula $\mathbf{AGoal}_i\varphi$ can also be read ‘agent i wants φ to be true’.

3.2 Semantics

We use a standard possible worlds semantics. Models of the logic $\mathbf{L}$ ($\mathbf{L}$ -models) are tuples $M = \langle W, \mathcal{B}, \mathcal{G}, \mathcal{T}, \mathcal{X}, \mathcal{V} \rangle$ where:

- W is a nonempty set of possible worlds or states;
- $\mathcal{B} : AGT \rightarrow W \times W$ maps every agent $i \in AGT$ to a serial, transitive and Euclidean relation $\mathcal{B}_i$ between worlds in W ;
- $\mathcal{G} : AGT \rightarrow W \times W$ maps every agent $i \in AGT$ to a serial relation $\mathcal{G}_i$ between worlds in W ;
- $\mathcal{T} : AGT \times AGT \times 2^{AGT^*} \rightarrow W \times W$ maps every agent $i \in AGT$ and non-empty set of agents $C \in 2^{AGT^*}$ to a transitive relation $\mathcal{T}_{i,j,C}$ between worlds in W ;
- $\mathcal{X} : W \rightarrow W$ is a total function mapping every state in W to its successor state;
- $\mathcal{V} : ATM \rightarrow 2^W$ is a valuation function.

Accessibility relations on W can be viewed as functions from W to 2^W . Therefore, we write $\mathcal{B}_i(w) = \{v | (w, v) \in \mathcal{B}_i\}$, $\mathcal{G}_i(w) = \{v | (w, v) \in \mathcal{G}_i\}$ and $\mathcal{T}_{i,j,C}(w) = \{v | (w, v) \in \mathcal{T}_{i,j,C}\}$.

The set $\mathcal{B}_i(w)$ is the *information state* of agent i at world w : the set of worlds that agent i considers possible at world w . The set $\mathcal{G}_i(w)$ is the *preference state* of agent i at world w : the set of worlds that agent i prefers at world w . The set $\mathcal{T}_{i,j,C}(w)$ is the *communication state* of agent i with respect to agent j in the presence of group C at world w : the set of worlds that are compatible with what agent i told to agent j in front of group C at world w .

$\mathbf{L}$ -models are supposed to satisfy the following additional constraints. For every world $w \in W$, for all $i, j \in AGT$, for all $C \in 2^{AGT^*}$, if $z \in C \cup \{i, j\}$ we have:

- S1 if $v \in \mathcal{B}_i(w)$ then $\mathcal{G}_i(v) \subseteq \mathcal{G}_i(w)$;
- S2 if $v \in \mathcal{B}_i(w)$ then $\mathcal{G}_i(w) \subseteq \mathcal{G}_i(v)$;
- S3 if $v \in \mathcal{B}_z(w)$ then $\mathcal{T}_{i,j,C}(v) \subseteq \mathcal{T}_{i,j,C}(w)$;
- S4 if $v \in \mathcal{B}_z(w)$ then $\mathcal{T}_{i,j,C}(w) \subseteq \mathcal{T}_{i,j,C}(v)$.

Constraints S1 and S2 are about positive and negative introspection for goals. They are together equivalent to: if $v \in \mathcal{B}_i(w)$ then $\mathcal{G}_i(w) = \mathcal{G}_i(v)$. This means that worlds that are preferred by agent i are also preferred by agent i from those worlds that he considers possible.

Constraints S3 and S4 are about positive and negative introspection for communication, and are together equivalent to: if $v \in \mathcal{B}_z(w)$ then $\mathcal{T}_{i,j,C}(v) = \mathcal{T}_{i,j,C}(w)$, for every $z \in C \cup \{i, j\}$. Suppose that $z \in C \cup \{i, j\}$. Then, S3 and S4 together means that: worlds that are compatible with what agent i told to agent j in front of group C , are also compatible with what agent i told to agent j in front of group C from those worlds that agent z considers possible.

Given a model M , a world w and a formula φ , we write $M, w \models \varphi$ to mean that φ is true at world w in M . The rules defining the truth conditions of Boolean constructions are entirely standard. The truth conditions of modalities Bel_i , Goal_i , $\text{Tell}_{i,j,C}$ and $\mathbf{X}$ are defined as follows:

- $M, w \models \text{Bel}_i\varphi$ iff $M, v \models \varphi$ for all v such that $v \in \mathcal{B}_i(w)$;
- $M, w \models \text{Goal}_i\varphi$ iff $M, v \models \varphi$ for all v such that $v \in \mathcal{G}_i(w)$;
- $M, w \models \text{Tell}_{i,j,C}\varphi$ iff $M, v \models \varphi$ for all v such that $v \in \mathcal{T}_{i,j,C}(w)$;
- $M, w \models \mathbf{X}\varphi$ iff $M, v \models \varphi$ for $v = \mathcal{X}(w)$.

We write $\models_{\mathbf{L}} \varphi$ if φ is *valid* in $\mathbf{L}$ (φ is true in all $\mathbf{L}$ -models).

3.3 Axiomatization

Fig. 2 contains the axiomatization of the logic $\mathbf{L}$.

(KD45 _{Bel})	All KD45-principles for the operators Bel_i
(KD _{Goal})	All KD-principles for the operators Goal_i
(K4 _{Tell})	All K4-principles for the operators $\text{Tell}_{i,j,C}$
(K _X)	All K-principles for the operators $\mathbf{X}$
(PI _{Goal})	$\text{Goal}_i\varphi \rightarrow \text{Bel}_i\text{Goal}_i\varphi$
(NI _{Goal})	$\neg\text{Goal}_i\varphi \rightarrow \text{Bel}_i\neg\text{Goal}_i\varphi$
(PI _{Tell})	$\text{Tell}_{i,j,C}\varphi \rightarrow \text{Bel}_i\text{Tell}_{i,j,C}\varphi$ (if $z \in C \cup \{i, j\}$)
(NI _{Tell})	$\neg\text{Tell}_{i,j,C}\varphi \rightarrow \text{Bel}_i\neg\text{Tell}_{i,j,C}\varphi$ (if $z \in C \cup \{i, j\}$)
(Funct _X)	$\mathbf{X}\varphi \leftrightarrow \neg\mathbf{X}\neg\varphi$

Figure 2. Axiomatization of $\mathbf{L}$

We have all principles of the normal modal logic KD45 for every belief operator Bel_i . Thus, an agent cannot have inconsistent beliefs (i.e. $\neg(\text{Bel}_i\varphi \wedge \text{Bel}_i\neg\varphi)$), and he has positive and negative introspection over his beliefs (i.e. $\text{Bel}_i\varphi \rightarrow \text{Bel}_i\text{Bel}_i\varphi$ and $\neg\text{Bel}_i\varphi \rightarrow \text{Bel}_i\neg\text{Bel}_i\varphi$). We have all principles of the normal modal logic KD for every goal operator Goal_i . Thus, an agent cannot have inconsistent goals (i.e. $\neg(\text{Goal}_i\varphi \wedge \text{Goal}_i\neg\varphi)$). Moreover, we have all principles of the normal modal logic K4 for every communication operator $\text{Tell}_{i,j,C}$. Thus, i ’s action of telling to j that φ entails i ’s action of telling to j that i tells to j that φ (i.e. $\text{Tell}_{i,j,C}\varphi \rightarrow \text{Tell}_{i,j,C}\text{Tell}_{i,j,C}\varphi$). In other words, the action of telling something to someone has a self-referential nature.

Axioms PI_{Goal} and PI_{Tell} are standard axioms of positive and negative introspection for goals: if an agent has the goal (resp. does not have the goal) that φ , he believes this.

Finally, $\mathbf{PI}_{\text{Tell}}$ and $\mathbf{NI}_{\text{Tell}}$ are corresponding principles of positive and negative introspection for communication. According to Axiom $\mathbf{PI}_{\text{Tell}}$, if agent i told to agent j that φ in front of an audience C then agent i , agent j and every agent in the audience C believes this. According to Axiom $\mathbf{NI}_{\text{Tell}}$, if agent i did not tell to agent j that φ in front of the agents in C then agent i , agent j and every agent in C believes this. This means that if an agent i tells (resp. does not tell) something to someone in front of an audience C then this is public in the group $C \cup \{i, j\}$ including the speaker, the addressee, and all agents in the audience.

REMARK. Note that we did not include a general inclusion principle of the form $\mathbf{Tell}_{i,j,C}\varphi \rightarrow \mathbf{Tell}_{i,j,B}\varphi$ for $B \subseteq C$ stating that if B is a subgroup of C and i told to j that p in front of C then i also told to j that p in front of B . In fact, we want to be able to model situations in which an agent i told something in secret to another agent j (while all other agents were not hearing), and he told the contrary to j in front of a large group including j . For example, Bill might tell in secret to Mary that he loves Ann, i.e. $\mathbf{Tell}_{\text{Bill},\text{Mary},\{\text{Mary}\}}\text{BillLovesAnn}$, while Bill tells to Mary that he does not love Ann when he is in front of Mary and Bob (because Bill wants that Bob does not know that he loves Ann), i.e. $\mathbf{Tell}_{\text{Bill},\text{Mary},\{\text{Mary},\text{Bob}\}}\neg\text{BillLovesAnn}$.

We call $\mathbf{L}$ the logic axiomatized by the principles given in Fig. 2. We write $\vdash_{\mathbf{L}} \varphi$ if φ is a $\mathbf{L}$ -theorem.

Theorem 1 *The logic $\mathbf{L}$ is completely axiomatized by the principles in Fig. 2.*

PROOF. It is a routine task to check that the axioms of the logic $\mathbf{L}$ correspond one-to-one to their semantic counterparts on the models. In particular, $\mathbf{KD45}_{\text{Bel}}$ corresponds to the fact that every $\mathcal{B}_i$ is a serial, transitive and Euclidean relation; $\mathbf{KD}_{\text{Goal}}$ corresponds to the fact that every $\mathcal{G}_i$ is a serial relation; $\mathbf{K4}_{\text{Tell}}$ corresponds to the fact that every $\mathcal{T}_{i,j,C}$ is a transitive relation. Moreover, $\mathbf{PI}_{\text{Goal}}$ and $\mathbf{NI}_{\text{Goal}}$ correspond respectively to the constraint S1 and to the constraint S2 on $\mathbf{L}$ -models, $\mathbf{PI}_{\text{Tell}}$ and $\mathbf{NI}_{\text{Tell}}$ correspond respectively to the constraint S3 and to the constraint S4 on $\mathbf{L}$ -models, and $\mathbf{Funct}_X$ correctly axiomatizes the successor function X .

It is routine, too, to check that all of our axioms are in the Sahlqvist class. This means that the axioms are all expressible as first-order conditions on models and that they are complete with respect to the defined model classes, cf. [3, Th. 2.42]. ■

The following are examples of $\mathbf{L}$ theorems.

Proposition 1 *For every $i, j \in AGT$ and for every $C \in 2^{AGT^*}$ we have:*

- $$(1a) \quad \vdash_{\mathbf{L}} \mathbf{Tell}_{i,j,C}\varphi \leftrightarrow \bigwedge_{z \in C \cup \{i,j\}} \mathbf{Bel}_z \mathbf{Tell}_{i,j,C}\varphi$$
- $$(1b) \quad \vdash_{\mathbf{L}} \neg \mathbf{Tell}_{i,j,C}\varphi \leftrightarrow \bigwedge_{z \in C \cup \{i,j\}} \mathbf{Bel}_z \neg \mathbf{Tell}_{i,j,C}\varphi$$

According to Theorem 1a, agent i told to agent j that φ in front of the audience C if and only if i, j and every agent in the audience believes this. According to Theorem 1b, agent i did not tell to agent j that φ in front of the audience C if and only if i, j and every agent in the audience believes this.

4 A logical analysis of delegation

In the rest of the paper we will use the modal logic $\mathbf{L}$ in order to provide a logical analysis of delegation. We will first use this logic in or-

der to define some normative concepts like the concept of obligation-to-be and the concept of obligation-to-do (Section 4.1). Then, we will use it in order to define request and order (Section 4.2). Finally (in Section 4.3), we will first define the concept of power to command and the concept of delegation. We will conclude with a clarification of the logical relationships between delegation and obligation, that is, we will explain why a delegation act by i towards j will create an obligation for j to perform the action delegated by i .

4.1 Some normative concepts

Let us introduce a nonempty finite set of symbols denoting social roles $ROLE = \{x, y, \dots\}$. The function

$$\mathcal{F}_{\text{play}} : ROLE \longrightarrow 2^{AGT^*}$$

maps every social role to a nonempty set of agents, and $\mathcal{F}_{\text{play}}(x) = C$ just means that C is the set of agents in the society playing role x . In the set $ROLE$ we distinguish a specific role called *Auth*. If $i \in \mathcal{F}_{\text{play}}(\text{Auth})$, it means that agent i plays the role of legal authority in the society. Legal authorities are those agents that provide the criteria for the existence and the validity of a given norm in a society. In particular, a given norm is valid in the society if and only if the legal authorities recognize it as a norm. The term legal authority is for us a very general term that in certain situations is synonymous of the terms leader or legislator. For example, a contract stipulated by two agents is valid (and consequently the obligations stemming from it are valid) if and only if the legal authority (the notary) recognizes it as a valid contract.

We are interested here in defining a notion of norm based on its recognition by legal authorities. To this aim, we first define the following concept of official belief:

$$\mathbf{OffBel} \varphi \stackrel{\text{def}}{=} \bigwedge_{i \in \mathcal{F}_{\text{play}}(\text{Auth})} \mathbf{Bel}_i \varphi$$

We say that φ is officially believed or officially recognized to be true (noted $\mathbf{OffBel} \varphi$) if and only if, all legal authorities believe that φ is true. From the previous concept of official belief, we can define the concept of obligation based on the recognition by legal authorities.

$$\mathbf{Obl} \varphi \stackrel{\text{def}}{=} \mathbf{OffBel} (\neg \varphi \rightarrow V)$$

We say that φ is obligatory (noted $\mathbf{Obl} \varphi$) if and only if it is officially believed that the states in which φ is false are *bad* states, where V is a special propositional atom used for labeling sub-ideal states (also called violation states) as in Anderson's reduction of deontic logic to alethic logic [1]. The concept of obligation-to-do is then defined in the standard way as follows:

$$\mathbf{Obl}_i \alpha \stackrel{\text{def}}{=} \mathbf{Obl} \alpha_i$$

We say that agent i has the obligation to do action α (noted $\mathbf{Obl}_i \alpha$) if and only if it is obligatory that agent i does action α .

4.2 Definitions of request, order and delegation

As emphasized in Section 2, the concept of delegation is tightly connected with the concepts of request and order. So, an analysis of delegation calls for a clarification of the concepts of request and order.

As anticipated above, we just consider here the external (overt) conditions of speech acts, that is, the conditions referring to what

the speaker overtly expresses while performing the speech act. In particular, we define request and order on the basis of Condition C and Condition E given in Section 2.

So, we say that agent i made a request to agent j in front of an audience C to do action α (noted $\mathbf{Request}(i, j, C, \alpha)$) if and only if, i told to j in front of the audience C that i wants that j does action α :

$$\mathbf{Request}(i, j, C, \alpha) \stackrel{\text{def}}{=} \mathbf{Tell}_{i, j, C} \mathbf{AGoal}_i \alpha_j$$

Moreover, we say that agent i ordered agent j in front of an audience C to do action α (noted $\mathbf{Order}(i, j, C, \alpha)$) if and only if, i told to j in front of the audience C that j does action α and that if in the next state j does not perform this action then this counts as a violation of a norm by j :

$$\mathbf{Order}(i, j, C, \varphi) \stackrel{\text{def}}{=} \mathbf{Tell}_{i, j, C} (\mathbf{AGoal}_i \alpha_j \wedge (\mathbf{X} \neg \alpha_j \rightarrow \mathbf{V}))$$

To simplify our exposition, in the rest of the paper we will omit the third argument concerning the audience in the two predicates for request and order when $C = \mathcal{F}_{\text{play}}(\text{Auth})$. That is, we will simply write $\mathbf{Request}(i, j, \varphi)$ instead of $\mathbf{Request}(i, j, \mathcal{F}_{\text{play}}(\text{Auth}), \varphi)$, and $\mathbf{Order}(i, j, \varphi)$ instead of $\mathbf{Order}(i, j, \mathcal{F}_{\text{play}}(\text{Auth}), \varphi)$. Therefore, $\mathbf{Request}(i, j, \varphi)$ and $\mathbf{Order}(i, j, \varphi)$ are simply read “agent i made a request to agent j to ensure φ ” and “agent i ordered agent j to ensure φ ”.

4.3 Creation of obligations through delegation

We conclude our formal analysis by clarifying the relationship between delegation and obligation, that is, by explaining how a delegation act by i directed towards j will create an obligation for j to perform the action delegated by i .

The following notion of power to command is a fundamental building block of our definition of delegation:

$$\mathbf{CPower}(i, j, \alpha) \stackrel{\text{def}}{=} \mathbf{OffBel} ((\mathbf{Order}(i, j, \alpha) \rightarrow (\mathbf{X} \neg \alpha_j \rightarrow \mathbf{V}))$$

We say that agent i has the power to command agent j to do α (noted $\mathbf{CPower}(i, j, \alpha)$) if and only if the legal authorities recognize that if agent i ordered agent j to do action α and in the next state j does not perform this action then, this counts as a violation of a norm by j .

Delegation is defined by means of these concepts of order and of power to command. In particular, we say that agent i delegated action α to agent j (noted $\mathbf{Deleg}(i, j, \varphi)$) if and only if i ordered j to do action α and i has the power to command j to do action α :

$$\mathbf{Deleg}(i, j, \varphi) \stackrel{\text{def}}{=} \mathbf{Order}(i, j, \varphi) \wedge \mathbf{CPower}(i, j, \alpha)$$

The following theorem is a fundamental contribution of the present analysis since it sheds light on the hidden path from delegation to obligations.

Proposition 2 For every $i, j \in \text{AGT}$ we have:

$$\vdash_L \mathbf{Deleg}(i, j, \alpha) \rightarrow \mathbf{Obl}_j \alpha$$

⁵ Note that i 's power to command agent j to do action α should be conceived as a specific form of institutional power based on so-called constitutive rules [21] recognized to be valid by the legal authorities of the form “ i 's act of commanding agent j to do action α counts as i 's act of ensuring that j has the obligation to accomplish that action” (see, e.g., [17, 15, 12] for some logical accounts of *counts as*). The relationship between constitutive rules and delegation power will not be analyzed here.

The previous L-theorem just says that if i delegated action α to j (on the basis of the recognition by the legal authorities of i 's power to command j to do action α) then, as a consequence, j has the obligation to do action α . Let us go back to the example given in Section 2. If agent i_1 , the president of a company, delegated to agent i_2 , an employee of the company, the task of representing the company at a journalist meeting (i.e. $\mathbf{Deleg}(i_1, i_2, \text{reprCompany})$) then, necessarily, i_2 has the obligation to represent the company at the journalist meeting (i.e. $\mathbf{Obl}_{i_2} \text{reprCompany}$), since the legal authorities recognize i_1 's power to command i_2 to represent the company at the journalist meeting.

Before concluding, let us add a short remark. We are aware that there are cases of delegation in which the delegant's power to command is a form of absolute power which does not need to be legitimated by external legal authorities. This is for instance the case of the absolute power of a sovereign or of a general of an army. One might say that in this case, the legal authority and the agent to whom the power to command is conferred coincide, that is, we have $\mathbf{CPower}(i, j, \alpha)$ and $\mathcal{F}_{\text{play}}(\text{Auth}) = \{i\}$. For example, it is the general himself who legitimates his power to command his soldier to do a certain action α , i.e. $\mathbf{CPower}(\text{general}, \text{soldier}, \alpha)$ and $\mathcal{F}_{\text{play}}(\text{Auth}) = \{\text{general}\}$. Note that, following the Hobbesian tradition, this form of absolute power is in turn founded upon an act of delegation by the members of the society (also called delegation of power). We postpone to future work an analysis of this form of delegation of power to a supreme authority.

5 Related works

Several authors working in the area of intersection between social sciences and computer science have been interested in the concept of delegation and have tried to clarify the role of delegation in organized social action. We here discuss some of the most important approaches to delegation.

Falcone & Castelfranchi's model of delegation. Falcone & Castelfranchi [9, 10] have proposed a model of delegation that has some similarities with the approach proposed in this work. They are interested in a specification of the cognitive constituents of delegation as a particular cognitive state (defined in terms of beliefs, goals, intentions) of the delegating agent. Castelfranchi & Falcone individuate several kinds of delegation. They introduce a first type of delegation called *weak delegation*, that is, the delegation based on exploitation, on the passive achievement by an agent i of a certain task. In weak delegation, an agent i just exploits in his plan a fully autonomous action of another agent j . In fact, i has only to recognize the possibility that j will realize a certain action and that this action ensures that the goal of i will be satisfied. In this case agent i “passively” awaits the satisfaction of his goals given his expectation that j will ensure it. Then, they have a second type of delegation called *mild delegation*, the delegation based on the active indirect achievement by i of the task. Agent i not only exploits agent j 's action for the achievement of his goals since he sees agent j 's intervention as fundamental for this, but also acts in order to induce j to perform the right course of action. Finally, they have a third type of delegation called *strong delegation* based on goal adoption. In strong delegation, agent i has a certain goal φ and decides to act in order to induce j to adopt his goal φ . Although Castelfranchi & Falcone recognize that strong delegation might be based on a request or order of the delegant to the delegate, they leave implicit the communicative aspect of delegation and do not consider in detail the relationships between delegation and the speech acts request and order. Finally,

Castelfranchi & Falcone's analysis does not consider the relationships between delegation, power to command and obligations which is a fundamental point in our analysis. That is, Castelfranchi & Falcone do not consider how i 's act of delegating to j an action α will create an obligation for j to perform the action, given the recognition by the legal authorities of i 's power to command j to do action α .

'Non-mentalistic' approaches to delegation. Recently other researchers have developed formal systems for reasoning about delegation. Many of these approaches try to express the concept of delegation without referring to mental states. Norman & Reed [18] analyze those forms of delegation where by issuing an imperative an agent i creates an obligation for another agent j to accomplish a given task. They exploit a logic of agentive action by using a *bringing it about* modal operator E_i similar to [15] and a deontic modality O . According to them a formula such as $E_i O E_j \varphi$ reading "agent i brings it about that the state of affairs holds in which it is obligatory for j to see to it that φ " corresponds to i 's action of issuing an imperative to j and expresses delegation. Santos et al. [19] proposes a similar analysis of delegation (or attribution) of responsibility. A similar approach to delegation is also proposed by Grossi et al. [13] in which delegation is taken as primitive action without being analyzed in terms of the cognitive states of the delegant, and what delegation does is just creating directed obligations, given that certain necessary preconditions for the creation of the obligation hold.

Although we agree with Norman & Reed [18], Santos et al. [19] and Grossi et al. [13] that delegation is responsible for the creation of obligations (see Section 4.3), we think that it is too simplistic to reduce delegation to something like "agent i brings it about that the state of affairs holds in which it is obligatory for j to see to it that φ " as Norman & Reed and Santos et al. do. The main problem with this approach is that it is not able to exclude from the definition of delegation all those situations where by performing a certain action, an agent i *accidentally* (*non intentionally*) brings it about that agent j is subject to a certain obligation. For example, by passing through the security gate at the airport with a suspicious hand luggage, a terrorist named Oscar it about that the state of affairs holds in which it is obligatory for the security service to search Oscar's hand luggage (suppose that there is a general rule saying that "security service must search all suspicious hand luggage"): $E_{Oscar} O E_{Security} Search_{Oscar} Luggage$. It seems quite odd to say that Oscar delegates the security service to search his hand luggage. Indeed, Oscar neither wants nor intends that the security service will search his hand luggage. It is rather the authority of the airport that having the intention to prevent terrorist attacks delegates to the security service the general task of searching all suspicious hand luggage and the more specific task of searching Oscar's luggage.

In our view in order to provide an adequate analysis of the concept of delegation, we must seriously consider both its *intentional dimension* and its *communicative dimension*. As emphasized in the present analysis, we can say that an agent i delegates a task α to another agent j only if i wants that j will accomplish this task, i communicates to j his intention, and i communicates to j that if he does accomplish the task he will incur the violation of a norm. The previous 'non-mentalistic' approaches completely ignore these two crucial dimensions of the concept of delegation.

6 Conclusion

We have presented in this work a conceptual analysis of delegation. We have conceived delegation as a social action involving two agents called the delegant and the delegate that the delegant performs by giv-

ing an order to the delegate, and that produces certain normative effects on the delegate and, in particular, an obligation for the delegate to perform the delegated task. An aspect that we intend to investigate in the future is the relationship between trust and delegation. Indeed, an agent i 's decision to delegate some task to another agent j is often based on i 's trust in j , that is, in many situations trust is a necessary precondition for delegation. To this aim, we intend to integrate the analysis presented here with our previous works on trust [16].

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