Analyzing Speech Acts Based on Dynamic Normative Logic

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Abstract. In a conversation, different kinds of speech acts are performed. Logic for communication has to deal with these various kinds of speech acts ([5]: 52). Additionally, for interpretation of conversations, it will be appropriate to take shared beliefs among communication partners into consideration. In this paper, we show that this problem can be dealt with in a framework that is a dynamic extension of the logic for normative systems.

Keywords: Speech acts · Dynamic normative logic · Logic for normative systems · Logic for communication · Shared attitudes · Common belief

1 Introduction

It is an aim of this paper to propose a logical framework for communication. The framework is based on *dynamic normative logic* (DNL) proposed in [19]. We interpret a communication as a game played by communication partners. A communication game consists of verbal and physical actions. Verbal actions can be interpreted as speech acts. As physical actions change physical sates in the world, successful performances of speech acts change normative states that are shared by communication partners. It may update shared beliefs and shared norms.

2 Logic for Normative Systems

In [12], I proposed a new logical framework that can be used to describe and analyze normative phenomena in general. I called this framework *Logic for Normative Systems* (LNS).[1] LNS takes not only assertive sentences but also normative sentences into consideration. In other words, LNS distinguishes two kinds of information, namely propositional and normative information. Assertive sentences, which express propositional information, are true or false. They describe

[1] A characteristic of LNS is its dynamic behaviors. LNS is quite flexible, so that LNS can be applied to describe complex normative problems including ethical problems. See [12,13].

Y. Nakano et al. (Eds.): JSAI-isAI 2013, LNAI 8417, pp. 98–114, 2014.
DOI: 10.1007/978-3-319-10061-6_7

physical facts and other kinds of facts such as social facts. If they properly describe the corresponding facts, then they are true. In contrast, normative sentences seem to have no truth value. They are related with social norms. They are accepted or rejected by a certain group and they influence the decision making of agents.

LNS is a quite flexible formal framework and can explicitly express both propositional and normative constraints. In LNS, the validity of assertive sentences remains independent of normative requirements, while that of normative sentences depends on the presupposed set of assertive sentences. The explicitness of LNS makes it possible to apply it to analysis of legal systems, paradoxes in deontic logics, and ethical problems.

In this paper, we modify the previous version of LNS, so that we can express mental states of agents.[2] Here, we mainly deal with belief states and normative states of agents. For the sake of simplicity, we use &, $\Rightarrow$, and $\Leftrightarrow$ as meta-logical abbreviations for *and*, *if ... then*, and *if and only if.*

Definition 1. *Suppose that each of T and OB be a set of sentences in First-Order Logic (FOL), more precisely a set of sentences in Many-sorted Logic.*[3]

- **(1a)** *A pair* $\langle T, OB\rangle$ *consisting of belief base T and obligation base OB is called a normative system (NS =* $\langle T, OB\rangle$*).*
- **(1b)** *A sentence q belongs to the belief set of normative system NS (abbreviated as* $\boldsymbol{B}_{NS}q$*)* $\Leftrightarrow$ *q follows from T.*
- **(1c)** *A sentence q belongs to the obligation set of NS (abbreviated as* $\boldsymbol{O}_{NS}q$*)* $\Leftrightarrow$ $T \cup OB$ *is consistent & q follows from* $T \cup OB$ *& q does not follow from T.*[4]
- **(1d)** *A sentence q belongs to the prohibition set of NS (abbreviated as* $\boldsymbol{F}_{NS}q$*)* $\Leftrightarrow$ $\boldsymbol{O}_{NS}\neg q$.
- **(1e)** *A sentence q belongs to the permission set of NS (abbreviated as* $\boldsymbol{P}_{NS}q$*)* $\Leftrightarrow$ $T \cup OB \cup \{q\}$ *is consistent & q does not follow from T.*
- **(1f)** *A normative system* $\langle T, OB\rangle$ *is consistent* $\Leftrightarrow$ $T \cup OB$ *is consistent.*
- **(1g)** *In this paper, we interpret that NS represents a normative system accepted by a person or by a group in a particular time interval. Thus, we insert what a person (or a group) believes to be true into the belief base and what he believes that it ought to be done into the obligation base.*

We read formulas of LNS as follows:

$\mathbf{B}_{NS}q$: "It is believed in NS that q."
$\mathbf{O}_{NS}q$: "It is obligatory in NS that q."

[2] The main difference between two versions of LNS consists in the use of some notions in (1a). We use now the notion *belief base* instead of *propositional system*. Some effects of this change will become visible, when we start to analyze interactions among normative systems of different agents.

[3] The many-sorted logic is reducible to FOL. Thus, this difference is not essential.

[4] In this paper, we require the consistency of T∪OB from two reasons, namely to justify the claim that obligation implies permission and to smoothly describe rule-following behaviors.

$\mathbf{F}_{NS}q$: "It is forbidden in NS that q."
$\mathbf{P}_{NS}q$: "It is permitted in NS that q."

Based on Definition 1, we can easily prove the following main theorems that characterize LNS.

Theorem 2. *The following sentences are meta-logical theorems of LNS. Here, we assume $NS = \langle T, OB \rangle$.*

(2a1) $(\boldsymbol{B}_{NS}(p \to q)$ *&* $\boldsymbol{B}_{NS}p) \Rightarrow \boldsymbol{B}_{NS}q$.
(2a2) $\boldsymbol{B}_{NS}p \Leftrightarrow T \vdash p$.
(2b1) $(\boldsymbol{O}_{NS}(p \to q)$ *&* $\boldsymbol{O}_{NS}p) \Rightarrow \boldsymbol{O}_{NS}q$.
(2b2) $\boldsymbol{F}_{NS}p \Leftrightarrow \boldsymbol{O}_{NS}\neg p$.
(2b3) $\boldsymbol{O}_{NS}p \Rightarrow \boldsymbol{P}_{NS}p$.
(2b4) $\boldsymbol{F}_{NS}p \Rightarrow$ *not* $\boldsymbol{P}_{NS}p$.
(2c) $\boldsymbol{B}_{NS}p \Rightarrow$ *(not* $\boldsymbol{O}_{NS}p$ *& not* $\boldsymbol{F}_{NS}p$ *& not* $\boldsymbol{P}_{NS}p)$.
(2d1) $(\boldsymbol{O}_{NS}(p \to q)$ *&* $\boldsymbol{B}_{NS}p) \Rightarrow \boldsymbol{O}_{NS}q$.
(2d2) $(\boldsymbol{O}_{NS}(p \wedge q)$ *& not* $\boldsymbol{B}_{NS}p) \Rightarrow \boldsymbol{O}_{NS}p$.
(2d3) $(\boldsymbol{O}_{NS}(p \wedge q)$ *&* $\boldsymbol{B}_{NS}p) \Rightarrow \boldsymbol{O}_{NS}q$.
(2d4) $(\boldsymbol{O}_{NS}(p \vee q)$ *&* $\boldsymbol{B}_{NS}\neg p) \Rightarrow \boldsymbol{O}_{NS}q$.
(2d5) $(\boldsymbol{O}_{NS}(p \wedge q)$ *&* $\boldsymbol{F}_{NS}p) \Rightarrow \boldsymbol{O}_{NS}q$.
(2e1) $(\boldsymbol{O}_{NS}\forall x_1, \ldots, \forall x_n(P(x_1, \ldots, x_n) \to Q(x_1, \ldots, x_n))$ *&* $\boldsymbol{B}_{NS}P(a_1, \ldots, a_n)$ *& not* $\boldsymbol{B}_{NS}Q(a_1, \ldots, a_n)) \Rightarrow \boldsymbol{O}_{NS}Q(a_1, \ldots, a_n)$.
(2e2) $(\boldsymbol{F}_{NS}\exists x_1, \ldots, \exists x_n(P(x_1, \ldots, x_n) \wedge Q(x_1, \ldots, x_n))$ *&* $\boldsymbol{B}_{NS}P(a_1, \ldots, a_n)$ *& not* $\boldsymbol{B}_{NS}\neg Q(a_1, \ldots, a_n)) \Rightarrow \boldsymbol{F}_{NS}Q(a_1, \ldots, a_n)$.

Proof. (2a1) is obvious, because modus ponens holds in FOL. To prove (2b1), suppose that $\mathbf{O}_{NS}(p \to q)$ & $\mathbf{O}_{NS}p$. Thus, $p \to q$ does not follow from T. Now, it is sufficient to show that q does not follow from T, because *modus ponens* shows that q follows from $T \cup OB$. However, since $q \to (p \to q)$ is a theorem of FOL, q does not follow from T. In a similar way, other theorems can be easily proved. □

In LNS, we have belief operator $\mathbf{B}_{NS}$ and normative operators $\mathbf{O}_{NS}$, $\mathbf{F}_{NS}$, and $\mathbf{P}_{NS}$, where all of these operators are relativized by the given normative system NS. This relativization is a main difference of LNS to modal logics. The theorem (2a2) shows that the belief set is not influenced by normative requirements. From Theorem 2, we can see how LNS differs from the doxastic logic. For example, LNS presupposes a particular theory T, so that the belief ascription becomes dependent on T, while doxastic logic characterizes belief in a more abstract manner.

Within LNS, iterations of operators are forbidden, while modal logics usually allow any iteration of modal operators. This is a limitation of LNS. However, we can imitate iterations of operators, as we show this in Sect. 2 (See (3b) and Table 1).

We will often use inference rule (2e1) in this paper. The content of (2e1) can be paraphrased as follows: If $\forall x_1, \ldots, \forall x_n(P(x_1, \ldots, x_n) \to Q(x_1, \ldots, x_n))$ is an obligation and you believe $P(a_1, \ldots, a_n)$, then $Q(a_1, \ldots, a_n)$ is an obligation, unless you believe that it was already done. The last condition is reasonable, because you need not do again what is already done.

3 Dynamic Normative Logic

In a previous work [19], I extended LNS and proposed *Dynamic Normative Logic* (DNL). DNL is a LNS complemented with information update device. Recently, the *Dynamic Epistemic Logic* (DEL) has been established as a framework for logical description of social interactions.[5] There are many extensions of DEL and some of them deal with communication problems and change of common beliefs [23]. DNL can be considered as an alternative framework for the same purpose. We can update normative system $\langle T, OB \rangle$ by extending the belief base T or obligation base OB with new information p (i.e. $T_{new} = T \cup \{p\}$ or $OB_{new} = OB \cup \{p\}$). In [19], based on DNL, I gave a full description of social interactions in a restaurant scene discussed by van Benthem ([2]: 4).

In this paper, we sometimes say *normative state of an agent* instead of *normative system*, when this agent has a particular normative system in certain time interval.[6] When NS is the normative system that A has in t, we say "A believes in time interval t that q" instead of "It is believed in NS that q" and "A believes in time interval t that it is obligatory that q" instead of "It is obligatory in NS that q". In general, we express ascriptions of beliefs and normative states as follows.

(3a) We use $ns(X, t)$ ($ns(X, t) = \langle bel(X, t), ob(X, t) \rangle$) to refer to the normative system that person X has in time t, where $bel(X, t)$ is the belief base of X in t and $ob(X, t)$ is the obligation base of X in t.

(3b) We use $ns(X > Y, t)$ to refer to the normative system that X ascribes to Y in time t. Furthermore, we use $ns(X > Y > Z, t)$ to refer to the normative system that X identifies in time t as the normative system that Y ascribes to Z. In this way, you may construct more complex ascriptions of normative systems.[7]

(3c) We require for any $ns(X > X, t)$ the following three conditions:
1. $bel(X > X, t)$ is consistent.
2. If $bel(X, t)$ is consistent, then $bel(X > X, t) = bel(X, t)$.
3. $ob(X > X, t) = ob(X, t)$.

$bel(X > X, t)$ is a normative system for an agent who has the ability of the complete introspection. As a matter of fact, based on (3c), we can easily prove the following fact: If $bel(X, t)$ is consistent, then for any formula q, ($\mathbf{B}_{ns(X,t)} q \Leftrightarrow \mathbf{B}_{ns(X>X,t)} q$). Thus, the belief part of this kind of agents roughly corresponds to the belief representation within the doxastic logic.[8]

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[5] For the development of the dynamic epistemic logic, you nay consult [2]. There, van Benthem characterizes the epistemic logic as logic of semantic information ([2]: 21). Compared to DEL, our approach in this paper is more syntactically orientated.

[6] As we see in the next section, a normative state of a person can be influenced by that of other persons.

[7] Note that all of theorems in Theorem 2 are applicable to $ns(X > Y, t)$ and $ns(X > Y > Z, t)$ as well, because they are all normative systems that satisfy all conditions in Definition 1.

[8] Note that $\mathbf{B}q \leftrightarrow \mathbf{BB}q$ is a theorem of the doxastic logic **D45**.

In (multiple) doxastic logic, it is possible to have a belief about other person's belief state. For example, $\mathbf{B}_i\mathbf{B}_j\mathbf{B}_k q$ means that i believes that j believes that k believes that q. The corresponding content can be expressed within LNS and DNL as $\mathbf{B}_{ns(i>j>k,t)}q$. Table 1 shows some examples of complex attitude ascriptions.

Table 1. Examples of complex attitude ascriptions

DNL-formulas	Reading of DNL-formulas
$\mathbf{B}_{ns(A,t)}q$	A believes in time t that q
$\mathbf{B}_{ns(A>B,t)}q$	A believes in time t that B believes that q
$\mathbf{B}_{ns(A>B>C,t)}q$	A believes in time t that B believes that C believes that q
$\mathbf{O}_{ns(A,t)}q$	A believes in time t that it is obligatory that q
$\mathbf{F}_{ns(A>B,t)}q$	A believes in time t that B believes that it is forbidden that q
$\mathbf{P}_{ns(A>B>C,t)}q$	A believes in time t that B believes that C believes that it is permitted that q

In order to take intentional attitudes into consideration, we interpret intention as a self-obligation. In DNL, a self-obligation has the form $\mathbf{O}_{ns(A,t)}$ $\exists t_1(do(A, action_k, t_1) \wedge t \leq t_1)$. This formula means: A believes in t that he himself is obligated to perform $action_k$. This self-obligation may cause A's performance of $action_k$, while A's knowledge of obligations of others, such as $\mathbf{O}_{ns(A,t)}$ $\exists t_1(do(B, action_k, t_1) \wedge t \leq t_1)$, has no such motivational power over A.

Now, we consider how to ascribe normative states to collective agents. We assume thereby a mereological ontology and interpret a collective agent as a mereological sum of atomic agents, because we want to avoid the use of set conception. Note that a set is an abstract entity, while a mereological sum of physical entities remains as physical.[9]

(4a) Let $BEL(X,t)$ be the belief set of (possibly collective) agent X in t. That means, any formula p that follows from $BEL(X,t)$ is already included in $Bel(X,t)$ as its element.

(4b) Let $A_1, \ldots, A_n$ be atomic agents. We construct the collective agent G as the mereological sum of $A_1, \ldots, A_n$ i.e. $G = A_1 + \cdots + A_n$. We assign G the normative system $ns(G,t)$, only if for any $A_k (1 \leq k \leq n)$ and any time t, $(BEL(G,t) \subseteq BEL(A_k,t)$ and $ob(G,t) \subseteq ob(A_k,t))$.

[9] In fact the notion of collective agent should be more carefully defined. See discussions about extended agents in [17,18]. For mereology, you may consult [25]. For four-dimensionalism, see [24]. For four-dimensional mereology, see [8,11].

(4c) To refer to groups of people, we accept the axiom system for *General Extensional Mereology* (GEM)[10]. We claim: For any time t, GEM is included in $bel(G, t)$.

(4d) From (4b) follows the following fact: For any atomic agent A who is a member of the collective agent G and for any formula p, $(\mathbf{B}_{ns(G,t)}p \Rightarrow \mathbf{B}_{ns(A,t)}p)$. This means that we may consider that $\mathbf{B}_{ns(G,t)}p$ expresses a shared belief of group G in time t.

(4e) We require for any $ns(G > G, t)$ the following three conditions:
1. $bel(G > G, t)$ is consistent.
2. If $bel(G, t)$ is consistent, then $bel(G > G, t) = bel(G, t)$.
3. $ob(G > G, t) = ob(G, t)$.

When normative system $ns(G > G, t)$ satisfies all of these conditions, we call it *common normative system for group* G and its belief *common belief*. In this case, it follows that $ns(G > G, t) = ns(G, t)$.

To express simple anaphoric relations, we use Skolem-symbols in this paper. We interpret (demonstrative) pronouns as a kind of Skolem symbols. So, not only d_k but also he_k, it_k, $this_k$, $that_k$, and the_k are used as Skolem-symbols.[11]

Definition 3. *Let $M = \langle U, V \rangle$, S be a set of formulas in which some elements of S contain Skolem-symbols, and μ be a variable assignment.*

(5a) *M^* is a Skolem expansion of M with respect to S iff (if and oly if)*
$M^* = \langle U, V^* \rangle$ & $V \subseteq V^*$ &
For all Skolem constant symbols d_k, $V^*(d_k) \in U$ &
For all n-ary Skolem function symbols d_k, $V^*(d_k)$ is a function from U^n into U.

(5b) *S is true according to M and μ iff*
There is M^* (M^* is a Skolem expansion of M with respect to S & S is true according to M and μ).

(5c) *S is true according to M iff*
S is true according to M and μ for all assignments μ.

Thus, Skolem-symbols are interpreted as constant symbols (or function symbols) whose referents can be determined from the viewpoint of the interpreter.

4 Describing Speech Acts in Dynamic Normative Logic

In this paper, we accept, by and large, Searle's analysis of speech acts [20] and his classification of illocutionary forces [21]. In Chap. 3 of [20], he distinguished *preparatory*, *sincerity*, and *essential conditions* for illocutionary acts. Preparatory conditions formulate indispensable conditions for the success of a speech act. The sincerity condition describes what kind of intentionality the speaker must have in order to sincerely perform certain kind of speech act. We call these

[10] GEM is the strongest mereological system. For GEM, you may consult [3] and [27].
[11] I did this kind of proposal in [9].

two kinds of conditions *pre+sin-conditions*. The essential condition expresses the essential feature of a speech act. For example, the undertaking of an obligation to perform a certain act is the essential condition of a promise ([20]: 60). This essential condition is the one we try to analyze in this section.

In [21], Searle distinguished five illocutionary forces, namely *Assertives*, *Directives*, *Commissives*, *Expressives*, and *Declarations*. He explains these classes of illocutionary forces in terms of a characterization of their illocutionary points.

(6a) [**Assertives**]. "The point or purpose of the members of the assertive class is to commit the speaker (in varying degrees) to something's being the case, to the truth of the expressed proposition." ([21]: 12)

(6b) [**Directives**]. "The illocutionary point of theses consists in the fact that they are attempts (or varying degrees, and hence, more precisely, they are determinates of the determinable which includes attempting) by the speaker to get the hearer to do something." ([21]: 13)

(6c) [**Commissives**]. "Commissives ... are those illocutionary acts whose point is to commit the speaker (again in varying degrees) to some future course of action." ([21]: 14)

(6d) [**Expressives**]. "The illocutionary point of this class is to express the psychological state specified in the sincerity condition about a state of affairs specified in the propositional content." ([21]: 15)

(6e) [**Declarations**]. "It is the defining characteristic of this class that the successful performance of one of its members brings about the correspondence between the propositional content and reality, successful performance guarantees that the propositional content corresponds to the world:" ([21]: 16–17)

Right now, there exist several formal approaches to speech act theory [26,29]. However, most of them failed to work as logic for communication. For example, we should deal with anaphoric relations that keep referents over performances of different types of speech acts, while most of existing frameworks failed to solve this problem.

In this paper, we express a successful performance of a speech act through an update of a normative system among communication partners. We also use Skolem symbols in order to deal with anaphoric relations.

At first, we introduce a function t_f that maps a time stamp to a time interval (see (7)).

(7) $\forall m \forall n (t_f(m) \leq t_f(n) \leftrightarrow m \leq n)$.

In this paper, we represent a speech act through the following representation schema:

$$[\textit{Speech act type}, \textit{Speaker}, \textit{Hearer}, \textit{Time stamp}, \textit{ok} \text{ (or } \textit{fail})] (\textit{Proposition}).$$

Speech act types roughly correspond to Searle's classification of illocutionary forces in [21], while our classification is a little bit more detailed than

Searle's. The fifth element of the head of the schema expresses whether the *pre+sin-conditions* for this type of speech act are fulfilled or not. For example, '$[assertive, s, h, n, ok]\ (p)$' means that the speaker s performs an assertive speech act to h in time $t_f(n)$ with the content that p, when the pre+sin-conditions for this speech act are fulfilled. When the pre+sin-conditions are not fulfilled, we write '$[sa\text{-}type,\ s, h, n, fail](p)$'. It is worth to note that this representation schema also contains information about the context of the utterance which can be used for interpreting the proposition stated in the same context. In other words, a representation schema for a speech act contains information about the speaker, the hearer, and the utterance time; this information can be used to interpret demonstratives and indexicals.[12]

It is our first assumption that a collective observation creates a common belief.

Definition 4. *Presupposition and Observation as Common belief*

(8a) *[**Common belief**]. Let G be a group of agents. Then, [common-belief,* $G, n](p) \Leftrightarrow \boldsymbol{B}_{ns(G>G,t)}p$.

(8b) *[**Presupposition**]. We stipulate:* $[presupposition, G, n]$ = *[common-belief,* $G, n]$. *This means that what is presupposed among G is also a common belief of G.*

(8c) *[**Observation**]. We stipulate:* $[observation, G, n]$ = *[common-belief,* $G, n]$. *This means that what is observed among G becomes a common belief of G.*

Now, we express a performance of speech acts as (local) information update of the given normative systems. The requirements in Definitions 5 and 6 express the update rules that describe the effects of observations and performed speech acts.

Definition 5. *Update of normative states*
Let $p(*_s/s, *_h/h, *_t/t_f(n))$ *be the formula that can be obtained from p by replacing all of* $*_s$, $*_h$, *and* $*_t$ *by* $s, h, t_f(n)$ *respectively.*[13] *In the following description,* $s+h$ *refers to the communication partners interpreted as the mereological sum of the speaker and the hearer. Let* $ns(s+h, t_f(n)) = \langle bel(s+h, t_f(n)), ob(s+h, t_f(n))\rangle$.

(9a) *[**Update of belief base**]. The belief update of a normative state in context of* (s, h, n) *is defined as follows: [[belief-update,* $s, h, n]\ (p(*_s, *_h, *_t))]$ $(ns(s+h, t_f(n))) = ns(s+h, t_f(n+1))$, *where* $bel(s+h, t_f(n+1)) = bel(s+h, t_f(n)) \cup \{p(*_s/s, *_h/h, *_t/t_f(n))\}$ *and* $ob(s+h, t_f(n+1)) = ob(s+h, t_f(n))$. *This means that a belief update changes only the belief base of both communication partners and their obligation base remains unchanged.*

[12] The classical work for semantics of demonstratives is formalized by D. Kaplan [7]. I proposed some improvements of Kaplan's framework [13,15,16].

[13] This replacement of *-terms by singular terms creates interpretations of demonstratives and indexicals.

(9b) *[**Update of obligation base**]. The obligation update of a normative state in context of* (s, h, n) *is defined as follows: [[obligation-update,* s, h, n*]* $(p(*_s, *_h, *_t))]$ $(ns(s+h,\ t_f(n))) = ns(s+h, t_f(n+1))$, *where* $bel(s+h, t_f(n+1)) = bel(s+h, t_f(n))$ *and* $ob(s+h, t_f(n+1)) = ob(s+h, t_f(n)) \cup \{p(*_s/s, *_h/h, *_t/t_f(n))\}$*. This means that an obligation update changes only the obligation base of both communication partners and their belief base remains unchanged.*

Definition 6. *Interpretations of simple speech acts*

(0a) *[**Assertives**]. We stipulate: [assertive,* s, h, n, ok*] = [belief-update,* $s, h,\ n$*]. This means that a successful performance of an assertive speech act can be interpreted as a belief update among communication partners.*

(10b) *[**Expressives**]. We stipulate: [expressive,* s, h, n, ok*] = [belief-update,* $s, h,\ n$*]. This means that a successful performance of an expressive speech act can be interpreted as a belief update among communication partners. It is a characteristic of expressive speech acts that their propositional content expresses a mental state of the speaker.*

(10c) *[**Directives**]. We stipulate: [directive,* s, h, n, ok*] = [obligation-update,* $s, h,\ n$*]. This means that a successful performance of a directive speech act can be interpreted as an obligation update among communication partners. It is a characteristic of directive speech acts that their propositional content expresses an action of the hearer.*

(10d) *[**Commissives**]. We stipulate: [commissive,* s, h, n, ok*] = [obligation-update,* $s, h,\ n$*]. This means that a successful performance of a commissive speech act can be interpreted as an obligation update among communication partners. It is a characteristic of commissive speech acts that their propositional content expresses an action of the speaker.*

The above update rules show that we always update the normative state of communication partners after a successful performance of a speech act. For example, suppose that A said to B that B should immediately go to the school. In this case, it is clear who is obliged, namely B. For the further inference, it is important to confirm that the information of this obligation is shared by both of the communication partners. This is the reason why we should update the normative state of $A + B$. Now, based on (4b), we can justify that after A's performance of the directive speech act, both A and B know that B should immediately go to the school.[14]

Questions can be interpreted as a kind of directive speech acts; they require certain responses from the hearer.

[14] From (4b) follows: $\mathbf{O}_{ns(A+B,t(n))}\exists t(\textit{go-to-school}(B,t) \wedge t(n) \leq t) \Rightarrow \mathbf{O}_{ns(A,t(n))}\exists t(\textit{go-to-school}(B,t) \wedge t_f(n) \leq t)$ & $\mathbf{O}_{ns(B,t(n))}\exists t(\textit{go-to-school}(B,t) \wedge t_f(n) \leq t)$.

Definition 7. *Speech acts for communication*

(11a) *[**Yes/No question**]. A Yes/No-question is a directive speech act with a requirement of a Yes/No answer. We can, therefore, replace [interrogative-yn, s, h, n, ok] $p(*_s, *_h, *_t)$ with [directive, s, h, n, ok] ($answer\text{-}yes_{(*_s,*_h,*_t)}(p) \vee answer\text{-}no_{(*_s,*_h,*_t)}(p)$), where $answer\text{-}yes_{(*_s,*_h,*_t)}(p) := (p(*_s, *_h, *_t) \rightarrow \exists t\ (say(*_h, *_s,$ 'Yes', $t) \wedge *_t < t))$ and $answer\text{-}no_{(*_s,*_h,*_t)}(p) := (\neg p(*_s, *_h, *_t) \rightarrow \exists t(say(*_h, *_s,$ 'No', $t) \wedge *_t < t))$. This means: Asked 'p?', the hearer should say 'Yes', when she (or he) believes that p, and she (or he) should say 'No', when she (or he) believes that ¬p.*

(11b) *[**Which question**]. [interrogative-which, s, h, n, ok] ($p_1 \vee \cdots \vee p_m$) is defined as the following obligation update: $ob(s + h, t_f(n + 1)) = ob(s + h, t_f(n)) \cup \{(p_k \rightarrow \exists t(say(h, s, \lceil p_k \rceil, t) \wedge t_f(n) < t)) : 1 \leq k \leq m\}$, where $\lceil p_k \rceil$ denotes an English sentence for proposition p_k! This means the following: Asked 'which of $\{p_1, \ldots, p_m\}$?', the hearer should say $\lceil p_k \rceil$, when she (or he) believes that p_k.*

(11c) *[**Wh-question**]. [interrogative-wh, s, h, n, ok]$(p(x))$ is defined as the following obligation update: $ob(s+h, t_f(n+1)) = ob(s+h, t_f(n)) \cup \{(p(x/c) \rightarrow \exists t(say(h, s, \lceil p(c) \rceil, t) \wedge t_f(n) < t))$: c is a singular term$\}$. This means the following: Asked 'which x is $p(x)$?', the hearer should say $\lceil p(c) \rceil$, when she (or he) believes that $p(c)$.*

These proposals show that we interpret here questions as a kind of conditional obligations. In other words, a question creates a certain kind of conditional obligation to the hearer.

5 Describing Declarations in Dynamic Normative Logic

Searle interpreted a declaration as a speech act that creates facts. However, some declarations, such as a declaration of a new law, create norms; a normative requirement that is stated by an authority can be accepted by people as their *new norms*. So, we distinguish, in this paper, two types of declarations.

Definition 8. *Declarations*
Let G be a group of people.

(12a) *[**Declaration of facts**]. We stipulate: [declaration-fact, s, G, n, ok] = [belief-update, s, G, n]. This means that a declaration of a fact can be interpreted as a belief update for a group. Usually, a declaration of a fact expresses a social fact and not a physical fact, because a physical fact holds independent of any collective belief.*[15]

[15] This claim implies a rejection of social constructivism of physical facts. For discussions about this topic, see [10,22].

(12b) ***[Declaration of obligations].*** *We stipulate: [declaration-obligation,* s, G*,* n*, ok] = [obligation-update,* s, G, n*]***.** *This means that a declaration of an obligation can be interpreted as an obligation update for a group. The amendment of laws deals with this kind of declaration of obligations. By the way, in such a case, we usually have to contract some of old articles, before we add the new articles, so that the law system remains consistent.*[16]

Declarations are speech acts that are addressed to a group and used to create social agreements and social norms. They are effective, only if the majority of the group members accept the corresponding authority of the speaker.

6 DNL-Analysis of Simple and Complex Speech Acts

In English, there are two different uses of conjunction, namely static and dynamic one. We can express this distinction in DNL. The statement 'p_1 and_{static} p_2' can be represented as $[assertive, s, h, n, ok](p_1 \wedge p_2)$. In this case, we obtain: $bel(s+h, t_f(n+1)) = bel(s+h, t_f(n)) \cup \{p_1(*_s/s, *_h/h, *_t/t_f(n)) \wedge p_2(*_s/s, *_h/h, *_t/t_f(n))\}$. The statement '$p_1$ $and_{dynamic}$ p_2' can be represented as $[assertive, s, h, n, ok](p_1)$ & $[assertive, s, h, n+1, ok](p_2)$. Then, we obtain $bel(s+h, t_f(n+2)) = bel(s+h, t_f(n)) \cup \{p_1(*_s/s, *_h/h, *_t/t_f(n))\} \cup \{p_2(*_s/s, *_h/h, *_t/t_f(n+1))\}$. In conclusion, the static conjunction is commutative, while the dynamic one is not.

N. Asher pointed out that speech acts, such as directives and questions, embed under some of natural language sentential connectives ([1]: 211). To examine Asher's claim, let us consider some of his examples:

(13a) Whoever stole this television bring it back.
(13b) Nobody move a muscle.
(13c) Get out of here or I'll call the police.
(13d) Go to the office and there you'll find the files I told you about.

DNL provides a straightforward analysis of these speech acts. Let $stole(x, *_h, *_t) := (television(this_1) \wedge atomic\text{-}part_{human}(x, *_h) \wedge \exists t(steal(x, this_1, t) \wedge t < *_t))$ and $bring(x, *_t) := (it_1 = this_1 \wedge \exists t\ (bring\text{-}back(x, it_1, t) \wedge *_t \leq t))$. Then, (13a) can be translated as $[directive, s, G, n, ok]\ (\forall x\ (stole(x, *_h, *_t) \rightarrow bring(x, *_t)))$. When this normative requirement is consistent with the previous normative state, according to (9b) and (10c), we obtain : $\mathbf{O}_{ns(s+G, t_f(n+1))}\ (\forall x\ (stole(x, G, t_f(n)) \rightarrow bring(x, t_f(n))))$. Now, suppose that John is the person who stole the television. Then, according to (2e1), when John believes that he believes in $t_f(n)$ that he stole the television, he is obligated to bring it back, unless he has already done it. Formally:

$$(\mathbf{B}_{ns(John, t_f(n+1))}\ stole(John, G, t_f(n))\ \&$$
$$not\ \mathbf{B}_{ns(John, t_f(n+1))}\ bring(John, t_f(n)) \Rightarrow$$
$$\mathbf{O}_{ns(John, t_f(n+1))}\ bring(John, t_f(n)).$$

[16] The AGM theory is an established formal framework for belief revision [4]. However, the revision of normative systems is quite complex and difficult to deal with the AGM theory.

(13b) can be analyzed in the same way as (13a). Let $move(x, *_t, t_1) := (move\text{-}muscle(x, t_1) \wedge *_t < t_1)$, where t_1 is a future reference time. Then, (13b) can be interpreted as $[directive, s, G, n, ok]$ $(\forall x\ (atomic\text{-}part_{human}(x, *_h) \rightarrow \neg move(x, *_t, t_1)))$. When this normative requirement is consistent with the previous normative state, according to (9b) and (10c), we obtain : $\mathbf{O}_{ns(s+G, t_f(n+1))}$ $\forall x\ (atomic\text{-}part_{human}(x, G) \rightarrow \neg move(x, t_f(n), t_1))$.Thus, because of (2e1), for any person a who knows that he himself is a member of G: $\mathbf{O}_{ns(a, t_f(n+1))}$ $\neg move(a, t_f(n), t_1)$, which is equivalent to $\mathbf{F}_{ns(a, t_f(n+1))}$ $move(a, t_f(n), t_1)$.

According to Searle's taxonomy of illocutionary forces, (13c) should be interpreted as a disjunction of a directive and a commissive speech act. However, as we saw in (10c) and (10d), we can interpret the both speech acts as two kinds of obligation update: $[obligation\text{-}update, s, h, n, ok]$ $(\exists t\ (get\text{-}out(*_h, here(*_s, *_t), t) \wedge *_t \leq t) \vee \exists t\ (call\text{-}police(*_s, t) \wedge *_t \leq t))$. In this formula, $here(*_s, *_t)$ refers to the place in which the speaker is located in $*_t$. When this normative requirement is consistent with the previous normative state, we obtain: $\mathbf{O}_{ns(s+h,\ t_f(n+1))}$ $(\exists t\ (get\text{-}out(h, here(s, t_f(n)), t) \wedge t_f(n) \leq t) \vee \exists t\ (call\text{-}police(s, t) \wedge t_f(n) \leq t))$. Based on (2d4), we can show that this formula implies a conditional meaning: 'If you do not get out of here, I'll call the police'. To show this, suppose that both s and h recognize that h does not get out of here: $\mathbf{B}_{ns(s+h, t_f(n+1))}$ $\neg\exists t\ (get\text{-}out(h, here(s, t_f(n)), t) \wedge t_f(n) \leq t))$. Then, because of (2d4), we obtain $\mathbf{O}_{ns(s+h, t_f(n+1))}$ $\exists t\ (call\text{-}police(s, t) \wedge t_f(n) \leq t)$, which means that the speaker is self-obligated to call the police. In conclusion, if both s and h know that h will not go out, then s is self-obligated to call the police.

In all of these three examples, I have shown that each of them can be interpreted as a *single speech act with a complex content.* Asher claims to interpret them as embedded speech acts. For example, he interprets (13b) in the following manner ([1]: 214): *for all* $x \in G$, *Imperative* $(\phi(x))$. Contrarily, we interpreted (13b) as $[directive, s, G, n, ok]$ $(\forall x (x \in G \rightarrow \phi(x)))$, and we concluded from this formal representation that *every a in G is obligated to perform an action such that* $\phi(a)$. These results suggest that the interpretation of speech acts is quite complex, because we have to consider the effect of normative inferences.

We interpret (13d) as a combination of a directive and an assertive speech act. To show this, we introduce two abbreviations: $go\text{-}office(*_h, *_t) := (office(the_1) \wedge \exists t\ (go\text{-}to(*_h, the_1, t) \wedge *_t < t))$ and $find\text{-}file(*_h, *_s, *_t) := (there_1 = the_1 \wedge file(the_2) \wedge \exists t\ (tell\text{-}about(*_s, *_h, the_2, t) \wedge t < *_t) \wedge \exists t\ (find(*_h, the_2, t) \wedge *_t < t))$. Now, we can interpret (13d) as follows: $[directive, s, h, n, ok]$ $(go\text{-}office(*_h, *_t))$ & $[assertive, s, h, n+1, ok]$ $(in(*_h, there_1, *_t) \rightarrow find\text{-}file(*_h, *_s, *_t))$. Thus, we obtain: $\mathbf{O}_{ns(s+h, t_f(n+1))}$ $go\text{-}office(h, t_f(n))$ & $\mathbf{B}_{ns(s+h, t_f(n+2))}$ $(in(h, there_1, t_f(n+1)) \rightarrow find\text{-}file(h, s, t_f(n+1)))$. This means that we read (13b) as an abbreviation of the following sentence: 'Go to the office! And if you are there, you'll find the files I told you about.'

7 DNL-Analysis of Speech Acts: Description of a Dialog

Our interpretation of speech acts can be applied to an analysis of dialogs. To demonstrate this, let us consider the following conversation.

A says, ‘Give me the book over there.’
B picks up a book and shows it to A. B asks, ‘This one?’
A answers, ‘No, it isn’t. The book behind it.’
B picks up another book and shows it to A. B asks, ‘This one?’
A answers, ‘Yes, that one.’
B brings this book to A.

This conversational scene contains different types of sentences, such as *declaratives*, *imperatives*, and *interrogatives*. It also contains actions and their observations. Collective observations play an important role for our representation of the scene, because they bring change of belief states of the communication partners.

We assume, at first, the following meaning presupposition for a linguistic community LC that includes A and B as its members.

Elementary Theory for LC : $ET^{LC} = \{(4c), (7), (14)\}$.
(14) $\forall x \forall y \forall z \forall n (bring(x, y, z, t(n)) \rightarrow give(x, y, z, t_f(n)))$.

We use Skolem constant symbols d_k, the_k, $this_k$, and $that_k$ to express anaphoric relations. For the sake of simplicity, we consider here only a case in which *pre+sin-conditions* of all intended speech acts in the conversation are satisfied. Furthermore, we assume: $ET^{LC} \subseteq bel(A + B, t_f(0))$.

Here, we interpret imperative sentence ‘Give me the book over there’ as a conditional obligation ‘If the book exists over there, then you ought to bring it to me’. This conditional obligation can be performed, only if the hearer understands which book the speaker means. This is the reason why the hearer asks several questions in order to identify which book the speaker means. TS in the left top cell in Table 2 expresses the time stamp. When an action of the participants takes place, the time stamp n is replaced by $n + 1$.

In $t_f(1)$, A orders B to bring him book d_1 that is located in some place far from A but in the vicinity of B. Through this order of A, B comes to be obligated to bring book d_1 to A. However, in $t_f(1)$, B is not sure which book is meant. So, B makes some trials of identifying the book which A actually meant. Finally in $t_f(5)$, B realizes which book he ought to bring to A. Thus, immediately after $t_f(5)$, B brings the book to A, so that B fulfills the original requirement of A.

To describe the development of a conversation, we introduce a *representation structure for normative systems* (RSNS). A RSNS is a n-tuple composed of the sets in form $bel(X, t_f(n))$, and $ob(X, t_f(n))$. Here, we take $\langle ob(A + B, t_f(1)), bel(A + B, t_f(6)), ob(A, t_f(4))\rangle$ as a RSNS of the above conversation. We can directly obtain the content of this RSNS by applying local update rules, namely (9a), (9b), (10a) $\sim$ (10d), and (11a) $\sim$ (11c), to the DNL-representation-schemata described in the right column of Table 2.

Now, you can easily prove: $\mathbf{B}_{ns(B,t_f(5))}\,(book(the_1) \wedge over\text{-}there(the_1, A, t_f(1)) \wedge this_3 = the_1)$. Because of the description of this situation, we may assume: *not* $\mathbf{B}_{ns(B,t_f(5))} \exists t(give(B, A, the_1, t) \wedge t_f(1) \leq t \leq t_f(5))$. Thus, $\mathbf{O}_{ns(B,t_f(5)))}$ $\exists t(give(B, A, this_3, t) \wedge t_f(1) \leq t)$. So, B tries to fulfill this obligation and

Table 2. DNL-analysis of a conversation

TS	Conversation	DNL-Analysis of speech acts and observations
1	A : 'Give me the book over there'	$[directive,\ A, B, 1, ok]\ (book(the_1)$ $\wedge\ over\text{-}there(the_1, *_s, *_t)) \rightarrow$ $\exists t(give(*_h, *_s, the_1, t) \wedge *_t \leq t))$ $[presupposition,\ A + B, 1]\ (book(the_1)$ $\wedge\ over\text{-}there(the_1, *_s, *_t))$
2	(B picks up a book and shows it to A.) B: 'This one?'	$[observation,\ A + B, 2]\ (pick\text{-}up\ (B, d_1, *_t)$ $\wedge\ book(d_1))$ $[presupposition,\ A + B, 2]\ (this_1 = d_1)$ $[interrogative\text{-}yn,\ B, A, 2, ok]\ (this_1 = the_1)$
3	A : 'No, it isn't. The book behind it'	$[assertive,\ A, B, 3, ok]\ (\neg\ this_1 = the_1)$ $[assertive,\ A, B, 3, ok]\ (book(the_2)$ $\wedge\ it_1 = this_1\ \wedge\ behind(the_2, it_1, *_t))$
4	(B picks up another book and shows it to A) B: 'This one?'	$[observation,\ A + B, 4]\ (pick\text{-}up\ (B, d_2, *_t)$ $\wedge\ book(d_2))$ $[presupposition,\ A + B, 4]\ (this_2 = d_2)$ $[interrogative\text{-}yn,\ B, A, 4, ok]\ (this_2 = the_1)$
5	A : 'Yes, that one'	$[presupposition,\ A + B, 5]\ (that_1 = this_2)$ $[assertive,\ A, B, 5, ok]\ (that_1 = the_1)$
6	B brings this book to A	$[presupposition,\ A + B, 6]\ (this_3 = that_1)$ $[observation,\ A + B, 6]\ (book(this_3) \wedge$ $bring(B, A, this_3, *_t))$

Table 3. RSNS for the conversation described in Table 2

$ob(A + B, t_f(1)) = \{\ldots, (book(the_1) \wedge\ over\text{-}there(the_1, A, t_f(1)))$ $\rightarrow \exists t(give(B, A, the_1, t) \wedge t_f(1) \leq t)\}$	
$bel(A + B, t_f(6))$	$ob(A, t_f(4))$
$\ldots$	$\ldots$
$book(the_1)\ \wedge\ over\text{-}there(the_1, A, t_f(1))$,	$answer\text{-}yes_{(A,B,t_f(2))}$
$pick\text{-}up(B, d_1, t_f(2)) \wedge book(d_1)$,	$(this_1 = the_1) \vee$
$this_1 = d_1$,	$answer\text{-}no_{(A,B,t_f(2))}$
$say(A, B,$ 'No', $t_f(3))$, $\neg this_1 = the_1$,	$(this_1 = the_1)$
$book(the_2) \wedge\ behind(the_2, it_1, t_f(3))$,	
$pick\text{-}up(B, d_2, t_f(4)) \wedge book(d_2)$,	$answer\text{-}yes_{(A,B,t_f(4))}$
$this_2 = d_2$, $that_1 = this_2$,	$(that_1 = the_1) \vee$
$say(A, B,$ 'Yes', $t_f(5)), that_1 = the_1$,	$answer\text{-}no_{(A,B,t_f(4))}$
$this_3 = that_1$,	$(that_1 = the_1)$
$book(this_3)\ \wedge\ bring(B, A, this_3, t_f(6))$	

brings the book to A in $t_f(6)$. Additionally, because of (2c), after the performance of this obligation, bringing the book to A ceases to be an obligation for B: $\mathbf{B}_{ns(B,t_f(6))}give(B, A, the_1, t_f(6))$ & $not\mathbf{O}_{ns(B,t(6))}\exists t(give(B, A, the_1, t) \wedge t_f(1) \leq t)$.

The construction of RSNS is cumulative, which is similar to the construction principle of *Discourse Representation Structure* (DRS) [6]. Thus, a RSNS can be considered as a background context for interpretation of new speech acts and new observations.

The original speech act theory of Austin and Searle analyzed utterances of simple sentences. In this section, we analyzed speech acts in context of a conversation. Speech acts are actions among many other kinds of actions and these actions and obligations change beliefs and normative states of the communication partners. As [19] points out, these kinds of social interactions can be interpreted as a cooperative game for achieving a collective goal. In our conversation example, getting a book that A wants to have is a shared goal for A and B. They try to find the most efficient way to achieve this goal.

8 Concluding Remarks

Recently, the dynamic epistemic logic (DEL) has been established as a framework for logical description of social interactions [2]. DNL can be considered as an alternative framework for the same purpose.[17] DNL can explicitly express conditions for social behaviors and describe interactions between social actions and normative inferences in detail. In this paper, we have shown how to describe and analyze a conversational development within DNL. As [19] suggests, DNL can be also used to describe games and simple language games described in [28].[18]

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[17] Discussions in [2] are restricted on various kinds of extension of proposi-tional modal logics, while DNL is a framework based on FOL.

[18] This research was supported by Global COE Program Center of Human-Friendly Robotics Based on Cognitive Neuroscience of the Ministry of Education, Culture, Sports, Science and Technology, Japan, and by Grant-in-for Scientific Research, Scientific Research C (24520014): The Construction of Philosophy of Science based on the Theory of Multiple Languages. Finally, I would like to thank two reviewers for useful comments.

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