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1. Introduction

In this paper, I present a dynamic semantics of permission sentences which analyzes the effects of deontic operators in discourse. Permission statements are known to be problematic for logical and linguistic theories based on standard systems of modal logic. These systems lead to predictions that are contrary to what natural language intuitions dictate. The tension between traditional modal deontic semantics and the proper characterization of the meaning of permission statements involving the deontic expression *may* has surfaced in the form of a number of so-called paradoxes or problems. The most relevant ones in the philosophical literature are (i) the paradox of free choice permisssion (Von Wright, 1969; Kamp, 1973) and (ii) Lewis'(1979) problem about spurious permission. My proposal gives a solution to these two problems and to the intrincacies of the meaning of boolean connectives in statements of this sort.

2. Free Choice Sentences

Consider the following sentences:

(1) a. You may eat a banana or a pear
    b. You may eat a banana

(2) a. You may go to San Francisco or stay in L.A.
    b. You may go to San Francisco

Sentences (1a) and (2a) are "free choice" permission statements. If the speaker utters (1a), he is giving the addressee permission to eat either a banana or a pear. In other words, the addressee is free to choose from the options presented from the speaker: eat a banana, eat a pear or both. Therefore, when the speaker gives permission to the addressee to eat a banana or a pear, he is giving him permission to eat a banana. Our intuitions are, then, that (1a) entails (1b) and (2a) entails (2b). Nevertheless, this represents a problem for standard systems of deontic logic, as noticed by Ross (1941), Von Wright (1969) and Kamp (1973,1979). In these systems, the entailment pattern that can be straigthforwardly derived is exactly the opposite, as the following proof shows:

(3) $\vdash$ P$\phi \rightarrow$ P($\phi \vee \psi$)

Proof:	P(ϕ)	Assumption
	P(ϕ) $\vee$ P(ψ)	$\vee$ intro.
	P($\phi \vee \psi$)	Modal theorem
	P(ϕ) $\rightarrow$ P($\phi \vee \psi$)	

Kamp (1973, 1979) found the accounts presented to date not satisfactory and proposed a solution in the spirit of Lewis' (1979) proposal. The solution consisted essentially in spelling out the semantics of commands and permission statements using some concepts that in a certain respect anticipate the dynamic view of meaning. A command, according to Kamp and Lewis, restricts the options for action of the addressee. A permission statement broadens the options for action of the addressee. The options for action of an agent at time t and world w are formally defined as the possible continuations of w after t in which the agent fulfills all his obligations and forbears doing the things from which he is prohibited.

Let $Per(w, t, B)$ denote the set of possible continuations of w after t in which the agent B fulfills his obligations and does not transgress anything he is prohibited from doing. Suppose that A utters in w at t the sentence *Clean my table!* and that B is the addressee of A's utterance. Let S be the set of worlds in which B cleans A's table. Then, the effect of A's command is to restrict the set of permitted continuations for B in w at t to those in which B cleans A's table:

(4) $Per(w, t, B) \longmapsto Per(w, t, B) \cap S$

A permission has the opposite effect in the set of permitted options for action of a given agent. If a speaker A tells B *You may* ϕ and S' is the set of worlds in which ϕ holds, then the effect of A's utterance is to enlarge the set of permitted options for B with S':

(5) $Per(w, t, B) \longmapsto Per(w, t, B) \cup S'$

In order to handle the entailment relation between (1a) and (1b) or (2a) and (2b), Kamp (1973) introduces a new notion of entailment, P(ermission)-entailment, defined as follows:

(6) ϕ P-entails ψ iff in every situation the set of worlds added to the options of the addressee through the use of ϕ includes the set of worlds added to the set of options through the use of ψ

Kamp (1979) abandons this solution because he considered it problematic with respect to Lewis' spurious permisssion problem, which we will discuss below. In a nutshell, the above definition of entailment predicts that when an agent is granting the permission stated in (7a) he is also granting (7b)—(7a) P-entails (7b).

(7) a. You may go to San Francisco
b. You may go to San Francisco and burn my house

His new solution is to propose that the meaning of *You may ϕ or ψ* is computed by calculating separately first the option space granted by *You may* ϕ and the option space granted by *You may* ψ, and combining the two of them by set-theoretic union. Then, writing $[\![\phi]\!]^{Per}{}_{w,t}$ to denote the set of worlds added to the options of the addressee in $< w, t >$ through the utterance of ϕ, the following holds:

(8) $[\![$ You may ϕ or ψ $]\!]^{Per}{}_{w,t} =$
$[\![$ You may ϕ $]\!]^{Per}{}_{w,t} \cup [\![$ You may ψ $]\!]^{Per}{}_{w,t}$

This resolves the entailment problem but, as pointed out by Rohrbaugh (1995), it predicts the equivalence of (9a) and (9b):

(9) a. I permit you to eat an apple or a pear
b. I permit you to eat an apple or I permit you to eat a pear

The above sentences are not equivalent, nor are the following ones, illustrating the fact that VP-level disjunction does not have the same effect in permission sentences as sentence level (or speech-act level) disjunction does.

(10) a. You may go to San Francisco or stay in L.A.
b. You may go to San Francisco or you may stay in L.A.

3. Strong and Weak Readings

Kamp (1979) also noticed that the sentence in (1a), repeated here as (11a), is ambiguous between two readings: a strong reading and a weak reading. In its "strong" or most salient reading it constitutes a free choice permission statement and entails (11b). In the "weak reading", (11a) simply states the speaker's ignorance about which disjunct is actually permitted. Then, (11b) entails (11a).

(11) a. You may eat a banana or a pear
b. You may eat a banana

3.1. Properties of the Strong Reading

The strong reading of a permisssion sentence makes it a free choice permission statement: the speaker is granting permission to the addresse (12a) or telling the addressee that he is granting permission to a third person/s (12b):

(12) a. You may go to San Francisco or stay in L.A.
b. John may go to San Francisco or stay in L.A.

The strong reading of a permission statement may be paraphrased by a performative sentence:

(13) *I hereby permit* you to go to San Francisco or stay in L.A

(14) John may buy an Opel or a Honda =
I hereby permit John to buy an Opel or a Honda

Third, as was discussed previously, the following holds: $\models \mathrm{P}(\phi \vee \psi) \rightarrow \mathrm{P}(\phi)$. The opposite direction does not hold: $\not\models \mathrm{P}(\phi) \rightarrow \mathrm{P}(\phi \vee \psi)$. Also, in the strong reading the equivalence in (15) holds.

(15) $\mathrm{P}(\phi \vee \psi) \equiv \mathrm{P}(\phi) \wedge \mathrm{P}(\psi)$

The following example illustrates the above equivalence. If the speaker is giving permission to John to buy an Opel or a Honda uttering (16a), then the permission granted is the same as the permission granted by (16b).

(16) a. John may buy an Opel or a Honda
b. John may buy an Opel and John may buy a Honda

There is a variety of the strong reading in which the disjunction connective is construed as exclusive *or*. For instance, in the following discourse, the parent is most likely granting permission to buy a car or take a vacation but not both.

(17) As a gift for your graduation, you may buy this expensive car or take the trip to the Bahamas that you wanted so much

3.2. Properties of the Weak Reading

A permission statement in its weak reading is a free choice permission report: it simply states the speaker's ignorance about which disjunct is actually permitted.

(18) John may buy an Opel or a Honda =
John has been granted permission to buy an Opel or a Honda (but I don't know which one)

In the weak reading of the above sentence, the speaker is reporting to the addressee that a third person has granted John permission to buy an Opel or a Honda. Consequently, permission statements in their weak reading may not be paraphrased by a performative sentence.

In comparison to the strong reading, it can be observed that the reverse entailment patterns arise: $P(\phi \vee \psi) \rightarrow P(\phi)$ does not hold, but $P(\phi) \rightarrow P(\phi \vee \psi)$ holds. Another entailment pattern of interest is the following one, illustrated in (19): $P(\phi) \vee P(\psi) \models P(\phi \vee \psi)$

(19) a. John may buy an Opel or John may buy a Honda $\models$
b. John may buy an Opel or a Honda

The weak reading of a permission sentence is a combination of a deontic and an epistemic statement. It cannot be considered a pure epistemic sentence. In other words, there is a subtle difference between the "permission report" reading and a pure epistemic reading. For instance, sentence (19a) in its epistemic reading means that it is possible that John buy a Opel or a Honda—perhaps because he has not decided yet about which one, or the speaker does not know the content of his decision, or John is hoping to get a loan to finance the car, etc. These are all circumstances that make the epistemic reading true. The permission report reading requires something different and much more specific, namely that the speaker is reporting the effect of a deontic permission statement.

4. Actions in Dynamic Semantics

The essence of the dynamic conception of semantics is to consider the basic meaning of a sentence to be not its truth-conditional content but its context-change potential. The meaning of an arbitrary expression in a state s is the change that it brings about to s. Let us assume that a conversation is in a discourse state s. Then, after processing a formula ϕ, the discourse moves to a state s', as depicted in (20). The state s' is like s except in those aspects that are not compatible with what ϕ expresses. Using a postfix notation, we write $s[\![\ \phi\ ]\!]$ for the meaning of the formula ϕ in a state s, as in (21).

(20) $\rightarrow s \rightarrow \phi \rightarrow s' \rightarrow$

(21) $s[\![\ \phi\ ]\!] = s'$ iff $s' \subseteq s$ and S

Different branches of dynamic semantics vary with respect to what they consider to be an information state. In DPL (Groenendijk and Stokhof, 1991) and DMG (Groenendijk and Stokhof,1990) a state is a set of assignments of values to variables. In DRT, a state corresponds to a Discourse Representation Structure K, such that K is the DRS built after processing a discourse (a finite sequence of sentences). In Dynamic Modal Logic a state is a set of worlds. This is the conception of a state that we will be adopting here. Furthermore, states will be epistemically construed, ie., we will be talking about the knowledge state of an agent rather than of a discourse state or a conversation state. This point is important in the type of account that we will be developing.

Dynamic action semantics adds to standard dynamic semantics a more refined analysis of action expressions. This analysis, I claim, is needed in order to give a correct account of the semantics of permission sentences. I present an extension of current dynamic modal frameworks (Veltman, 1996; Groenendijk, Stokhof and Veltman, 1995; Van Eijck and Cepparello, 1995) that incorporates a dynamic semantics for actions (DAS), along the lines proposed in Pratt's (1978) process semantics, Van der Meyden's (1996) logic of permission and Hamblin's (1987) analysis of imperatives. An action expression α is conceived of as denoting a program, ie. a set of sequences of states. Consider the action expression α = *Brutus killed*

Caesar.[1] Let us assume that the expression α denotes in a model M and state s a set with three members. Each sequence represents an execution of the action (Israel, Perry and Tutiya, 1993), i.e., the way of performing the action that results in that sequence of states.

(22) $s[\![\alpha]\!]_M = \{< s_{21}...s_{30} >, < s_{51}...s_{60} >, < s_{81}...s_{90}\}$

So, in the denotation of α above, each sequence represents a different execution of Brutus' action of killing Caesar in M. In one execution he stabs Caesar three times, in another he stabs Caesar thirty times, and in the third one he stabs him fifteen times. An execution of an action is a transition between states. The minimal requirement that all the sequences in the denotation of α have to satisfy is that in the initial state of the sequence Caesar is not dead, and in the final one he is.

(23)
$$\begin{array}{ccc} \bullet & \longrightarrow \quad \alpha \quad \longrightarrow & \bullet \\ s_{21} \not\models Dead(Caesar) & & s_{30} \models Dead(Caesar) \\ s_{51} \not\models Dead(Caesar) & & s_{60} \models Dead(Caesar) \\ s_{81} \not\models Dead(Caesar) & & s_{90} \models Dead(Caesar) \end{array}$$

A model for the language of DAS is a tuple $M = < W, S, P, \tau, V >$. W is a set of worlds and W = $\mathcal{P}(\mathcal{A})$, where $\mathcal{A}$ is a set of finitely many atomic sentences. This gives us the desired epistemic interpretation of worlds. A world is a set of facts—atomic sentences—in the knowledge base of an agent (Veltman, 1996). $S \subseteq \mathcal{P}(W)$ is the set of states, so a state is a set of possible worlds. The knowledge state of an agent is, then, a family of sets of facts, i.e., those that constitute possible epistemic alternatives. Information growth is represented as elimination of some of those possibilities.

P is a relation between states, $P \subseteq S \times S$, where $< s_i, s_j > \in P$ iff the transition from state s_i to state s_j represents a permitted state transition. Then, we say that a sequence of states $\sigma =< s_1...s_n >$ is permitted, $Perm(\sigma)$, iff every state transition in the sequence is in P. So, for instance, assume that $s[\![John\, got\, a\, pay\, raise]\!]_M = \{< s_{21}...s_{30} >, < s_{51}...s_{60} >\}$ and in s_{27} the proposition that John manipulated his sales report is true. Then, assuming that we are dealing with agents with standard ethical criteria, the first execution of the action is not permitted since it contains a state transition $< s_{26}, s_{27} >$

[1] A perhaps more intuitive alternative would be to consider *kill Caesar* as an action expression and relativize it to agents. Here we stick to the simpler option.

which is not permitted. This corresponds to the intuition that an execution of the action of getting a pay raise involving a manipulation of sales reports is not permitted, even if the rest of the transitions that bring about the completion of the action are permitted.

The function $\tau : \mathbf{A} \rightarrow \mathcal{P}(S^+)$ is the interpretation function for atomic action expressions $\alpha \in \mathbf{A}$, i.e., $\tau(\alpha)$ is the set of sequences of states denoted by α. Finally, the function V maps atomic propositional symbols ϕ to the set of worlds where the proposition holds.

The expressions of the language of DAS are interpreted in a state s as follows:

$s[\![\phi]\!] = \{w \in s | w \in V(\phi)\}$
$s[\![\neg\phi]\!] = \{w \in s | w \notin V(\phi)\}$
$s[\![\phi \wedge \psi]\!] = (s[\![\phi]\!])[\![\psi]\!]$
$s[\![\phi \vee \psi]\!] = \{w \in s | w \in V(\phi)$ or $w \in (s[\![\neg\phi]\!])[\![\psi]\!]\}$
$s[\![\alpha]\!] = \{\sigma | \sigma \in \tau(\alpha) \& first(\sigma) = s\}$ (where if $\sigma =< s_1 ... s_n >, first(\sigma) = s_1$ and $last(\sigma) = s_n$)
$s[\![\neg\alpha]\!] = \{\sigma | \sigma \notin \tau(\alpha) \& first(\sigma) = s\}$
$s[\![\alpha \cup \beta]\!] = s[\![\alpha]\!] \cup s[\![\beta]\!]$
$s[\![\alpha ; \beta]\!] = \{\sigma_1 \frown \sigma_2 | \sigma_1 \in \tau(\alpha)$ & $\sigma_2 \in \tau(\beta)$ & $first(\sigma_1) = s$ & $first(\sigma_2) = last(\sigma_1)\}$
$s[\![\alpha \rightarrow \phi]\!] = \{w \in s | \forall \sigma \in s[\![\alpha]\!][w \in last(\sigma) \& w \in V(\phi)]\}$
Weak permission:
$s[\![\Diamond\alpha]\!] = \{w \in s | \exists \sigma \in s[\![\alpha]\!][Perm(\sigma)]\}$
$s[\![\Box\alpha]\!] = s[\![\neg\Diamond\neg\alpha]\!]$
Strong permission:
$s[\![\pi\alpha]\!] = \{w \in s | \forall \sigma \in s[\![\alpha]\!][Perm(\sigma)]\}$

Let us explain the clauses of the definition in more detail. An expression ϕ denotes in a state s the set of those worlds in s in which ϕ holds. Similarly, $\neg\phi$ denotes in s the subset of s constituted by the worlds in which ϕ does not hold. Another way of expressing it is: $s[\![\neg\phi]\!] = s - \{w \in s | w \in V(\phi)\}$. The denotation of the expression $\phi \wedge \psi$ is computed by updating first the state s with ϕ and, as a result, eliminating from s the worlds that are not in $V(\phi)$. Then, the resulting state is updated with ψ, yielding a final state in which the worlds that are not in $V(\phi)$ and the worlds that are not in $V(\psi)$ are eliminated. The interpretation of dynamic disjunction has an exclusive flavour built in. Updating s with $\phi \vee \psi$ restricts s to the set of worlds that are either in $V(\phi)$ or are not in $V(\phi)$ but are in $V(\psi)$. The dynamic content of an action expression α in a state s is the set of sequences of states σ in the denotation of α, $\tau(\alpha)$, such that the first coordinate of σ is s. Obviously, this represents the "atemporal" value of actions, and it suffices for our purposes. The effect of the past and future operators would be captured as follows—where $\prec_t$ is an ordering relation between states: [2]

$$s[\![P(\alpha)]\!] = \{\sigma | \sigma \in \tau(\alpha) \& \exists s'[s' \prec_t s \& last(\sigma) = s']\}$$
$$s[\![F(\alpha)]\!] = \{\sigma | \sigma \in \tau(\alpha) \& \exists s'[s \prec_t s' \& first(\sigma) = s']\}$$

The clauses defining operations on actions are straightforward. The formula $\alpha \rightarrow \phi$ may be read as "if α then ϕ" or, perhaps more properly, "after α, ϕ". The effect of the modal operators $\Diamond$ and $\Box$ amounts to existential and universal quantification over sequences of states in the denotation of an action. so, for any action α and state s, $\Diamond\alpha$ is supported by s iff there is a permitted sequence in the denotation of α or, in other words, if some execution of α is permitted. Conversely, s supports $\Box\alpha$ iff all executions of α are permitted.

In the above paragraph we have introduced an informal notion of support. A more precise definition of this notion, and of the derived notions of entailment and equivalence between formulas, is as follows:

(24) Support/Acceptance: s $\Vdash \phi$ iff $s[\![\phi]\!]$ = s
Entailment: $\phi_1 ... \phi_n \models \psi$ iff $\forall s.((s[\![\phi_1]\!])...[\![\phi_n]\!]) \Vdash \psi$
Equivalence: $\phi \equiv \psi$ iff $\phi \models \psi$ & $\psi \models \phi$

5. Explaining the Strong/Weak Contrast

The strong and weak readings of permission sentences are represented by the presence of the strong (π) or weak ($\Diamond$) permission operator respectively. The strong operator models free choice, whereas the weak operator models partial ignorance about permission. Recall that, following Veltman(1996), we are conceiving of worlds as sets of atomic propositions in the knowledge state s of an agent. Then, the update of s with $\pi\alpha$ adds the information that all the executions of α are permitted. Consider one of our favourite examples:

[2]For any states s, s', in a sequence σ, $s \prec_t s'$ iff i(s) & j(s') & i $<$ j.

(25) You may take a banana or an apple

The strong reading of (25) states that any course of action in which the addressee takes a banana or an apple and such that it does not violate what the speaker considers permissible is permitted. This is precisely represented as follows:

(26) $s[\![\pi(Take(a\ banana)(you) \cup Take(an\ apple)(you))]\!] =$
$\{w \in s | \forall\sigma \in s[\![Take(a\ banana)(you) \cup$
$Take(an\ apple)(you)]\!][Perm(\sigma)]\} =$
$\{w \in s | \forall\sigma \in s[\![Take(a\ banana)(you)]\!] \cup$
$s[\![Take(an\ apple)(you)]\!][Perm(\sigma)]\}$

Now, the following facts are derived immediately applying the definitions:

Fact 1: $\pi(\alpha \cup \beta) \models \pi(\alpha)$
Fact 2: $\pi(\alpha \cup \beta) \equiv \pi(\alpha) \wedge \pi(\beta)$

Fact 1 captures in a straightforward way the entailment pattern of strong readings, whereas fact 2 derives the equivalence pointed out in (15). The reading of (17) and (27) with exclusive *or* requires an additional binary operation on actions ($\sqcup^e$):

$s[\![\alpha \sqcup^e \beta]\!] = s[\![\alpha]\!] \cup (s[\![\neg\alpha]\!])[\![\beta]\!]$

(27) You may buy a Porsche or a Corvette

Then, we prove again a fact that derives the equivalence between the exclusive reading of (27) and sentence (28):

Fact 3: $\pi(\alpha \sqcup^e \beta) \equiv \pi(\alpha) \vee \pi(\beta)$

(28) You may buy a Porsche or you may buy a Corvette

Let us now consider the weak reading of permission sentences. A knowledge state s supports $\Diamond\alpha$ iff an execution of α is considered permitted in s. If a speaker utters (29), then he is asserting that there is a course of action in which the addressee takes a banana or an apple such that it does not violate what the speaker considers permissible (30).

(29) You may take a banana or an apple

(30) $s[\![\Diamond(Take(a\ banana)(you) \cup Take(an\ apple)(you))]\!] =$
$\{w \in s | \exists\sigma \in s[\![Take(a\ banana)(you) \cup$
$Take(an\ apple)(you)]\!][Perm(\sigma)]\} =$
$\{w \in s | \exists\sigma \in s[\![Take(a\ banana)(you)]\!] \cup$
$s[\![Take(an\ apple)(you)]\!][Perm(\sigma)]\}$

Facts 4 and 5 are again immediately derived applying the definitions, and predict the properties explained in section 3.2 above.

Fact 4: $\Diamond(\alpha) \vee \Diamond(\beta) \models \Diamond(\alpha \cup \beta)$
Fact 5: $\Diamond(\alpha) \models \Diamond(\alpha) \vee \Diamond(\beta)$

Lewis' (1979) problem about permission does not arise in DAS, because permission sentences do not merely enlarge the option set of the addressee. Only sequences of states consisting of permitted transitions are in the denotation of the permission operators. Therefore, from (31a) one cannot infer (31b) because presumably most of the executions of the action *burn my house* are not permitted even if the two conjuncts are true in the same worlds.

(31) a. You may go to San Francisco
b. You may go to San Francisco and burn my house

6. Extensions of the Analysis

Rohrbaugh (1995) observes that permission sentences are decreasing in the internal argument of the verb: (32a) entails (32b).

(32) a. You may eat three apples
b. You may eat two apples

The decreasingness effect is predicted as a result of the presence of the permission operator and the execution-based sequence semantics for actions. We say that an action β is an extension of or encompasses an action α ($\alpha \leq \beta$) iff $\tau(\alpha) = \{\sigma_i | \exists\sigma_j \in \tau(\beta)$ such that σ_i is a subsequence of $\sigma_j\}$. Then, from the above definition and the semantics of the weak permission operator the following theorem can be proven:

Fact 6: $\alpha \leq \beta \wedge \pi\beta \models \pi\alpha$

This captures the intended inference in (32), but would erroneously predict that in (33) below, the speaker is also granting permission to write one essay, instead of taking the midterm. The special reading of (33) we call a "package deal" reading. In other words, the addressee is granted permission to perform an action in which he writes two essays instead of taking the midterm. This effect blocks the decrasingness property.

(33) Instead of taking the midterm you may write two essays

Another problem for some analysis of deontic sentences is that they validate the inference from (34a) to (34b). Nevertheless, this does not present any problem for the semantics that we are developing, because $\alpha \rightarrow \Diamond\beta$ does not entail $\Diamond(\alpha;\beta)$ in DAS.

(34) a. If you commit a traffic violation, then you may appeal it in court.
b. You may commit a traffic violation and appeal it in court.

When an imperative expression and a proposition are connected by the connectives *and*/*or*, the second conjunct is interpreted as a repercussion of the compliance (35a) or as a repercussion of the failure to comply (35b) with the command in the first conjunct.

(35) a. Go to San Francisco and Jane will be happy
b. Go to San Francisco or Jane will be unhappy.

The translations of the sentences in (35) into our language are as follows:

(36) a. $\Box Go\ to\, San\, Francisco \wedge Happy(Jane)$
b. $\Box Go\ to\, San\, Francisco \vee Unhappy(Jane)$

The above formulas have as their unique interpretation a "repercussive" one. In other words, according to the update semantics of $\wedge$, the proposition *Jane will be happy* is interpreted in the state resulting from updating s with the command *Go to San Francisco*. Similarly, the semantic clause for $\vee$ yields either the set of worlds in which the command is satisfied or the worlds resulting from interpreting the proposition *Jane will be unhappy* in a state in which the addressee is allowed not to go to San Francisco.

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