# Implicative inferences and causality in *enough* and *too* constructions[*]

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## 1   The problem

***Enough*** and ***too*** **(E&T) constructions** are 'optionally' implicative (Karttunen, 1971):

(1)   Juno was fast enough to win the race.  $\rightsquigarrow$ *Juno won the race.*

(2)   Juno was old enough to drink.  $\not\rightsquigarrow$ *Juno drank.*

Optionality is systematic along two dimensions:

- modal flavour of the adjective-complement relationship (Meier, 2003)
- aspectual marking (Hacquard, 2005; parallel to ability modals' *actuality entailments*, Bhatt, 1999)

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**Three puzzles:**

- **Karttunen's puzzle:** what determines which E&T constructions show implicative behaviour and which do not?
- **Hacquard's puzzle:** how does aspectual contrast produce/lift implicative behaviour?
- **Distributional puzzle:** how do E&T constructions resemble 'true' implicatives, and how do they differ?

**Goal:** an account of E&T complement inferences that treats them as truly implicative, while accounting for the three puzzles

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# 2   Implicative verbs

**Implicative verbs** (Karttunen, 1971) entail truth values for their complements; these entailments reverse under matrix negation

(3)   a.   Morgan **managed** to solve the riddle.                  $\vdash$ *Morgan solved the riddle.*
      b.   Morgan did not **manage** to solve the riddle. $\vdash$ *Morgan did not solve the riddle.*

(4)   a.   Morgan **failed** to solve the riddle.                  $\vdash$ *Morgan didn't solve the riddle.*
      b.   Morgan did not **fail** to solve the riddle.                  $\vdash$ *Morgan solved the riddle.*

- **logical problem:** what blocks the intuitively wrong conclusion that implicative assertions are equivalent to assertions of their complements?
- **answer:** presuppositional content associated with the implicative

The account I'll assume: Nadathur (2016)

- follows Karttunen (1971) on the presupposition/assertion 'division of labour'
- draws on Baglini & Francez (2016) in defining implicative presuppositions over formal relations in a *causal dynamics* (Schulz, 2011)

> **Proposal (Nadathur, 2016):**
>
> Given an implicative $I$ and a complement proposition $X$, $I(X)$:
>
> - **presupposes:** the existence of a (lexically-specified) causing factor/event $A$ with:
>     - $A$ is *causally necessary* for $X$
>     - $A$ is *causally sufficient* (in context) for $X$
>
> - **asserts:** that $A$ holds in the world of evaluation ($\neg I(X)$ asserts $\neg A$)
>
> ---
>
> **Today:** I argue that implicative behaviour in E&T constructions aligns with this account of implicativity, with respect to the underlying causal structure

# 3   Modality, necessity, and sufficiency

## 3.1   E&T implicative inference patterns

(A) **Dependence on modality:**

- deontic E&T constructions do not (systematically) implicate (Meier, 2003):

    (5)   a.   Juno was old enough to drink.                  $\not\leadsto$ *Juno drank.*

b. Juno was too young to drink. $\quad\not\leadsto$ *Juno did not drink.*

(B) Within the circumstantial cases, we also observe **dependence on adjective type:**

- 'passive' (often individual-level) properties implicate (strongly) in only one direction:

  (6)    a. Juno was tall enough to reach the branch. $\quad\not\leadsto$ *Juno reached the branch.*
        b. Juno was not tall enough to reach the branch. $\quad\leadsto$ *Juno did not reach the branch.*

- 'active' properties – **exercisable capacities** – implicate both ways:

  (7)    a. Juno was fast enough to win the race. $\quad\leadsto$ *Juno won the race.*
        b. Juno was too slow to win the race. $\quad\leadsto$ *Juno did not win the race.*

(C) English E&T inferences are **defeasible:**

(8)    Juno was not tall enough to reach the branch ... but she stood on her toes and jumped, and she got it.

(9)    Juno was fast enough to win the race ... but she didn't participate.
                      ... but she had an off day and did not win.

(D) **Dependence on aspect** (Hacquard, 2005):

- imperfectively-marked E&T at best implicate their complements:

  (10)    a. *Juno était assez rapide pour gagner la course, mais elle n'a jamais gagné.*
            Juno was-impf fast enough to win the race, but she never won.
        b. *Juno n'était pas assez rapide pour gagner la course, mais elle a toujours gagné.*
            Juno was-impf not fast enough to win the race, but she always won.

- perfectively-marked E&T *entail* their complements (like true implicatives):

  (11)    a. *Juno a été assez rapide pour gagner la course, #mais elle n'a pas gagné.*
            Juno was-pfv fast enough to win the race, #but she did not win.
        b. *Juno n'a été pas assez rapide pour gagner la course, #mais elle a gagné.*
            Juno was-pfv not fast enough to win the race, #but she won.

(E) **Qualifications** to Hacquard's generalization:

- deontic E&T do not entail under perfective aspect:

  (12)    *Juno a été assez grande pour boire de l'alcool, mais elle n'a l'a jamais bu.*
            'Juno was-pfv old enough to drink alcohol, but she never drank it.'

- to the extent that 'passive' circumstantial cases are felicitous in the perfective, aspect makes no difference with respect to entailment:

(13)   a.   *Juno était assez grande pour toucher la branche.*   $\nvdash$
            Juno was-impf tall enough to touch the branch.

       b.   *Juno a été assez grande pour toucher la branche.*   $\nvdash$
            Juno was-pfv tall enough to touch the branch.
            (*Juno became tall enough ...*)

## 3.2   Degree comparatives with a necessity condition

E&T constructions are analyzed as degree comparatives with a modal component (Bierwisch, 1987; Meier, 2003; von Stechow et al., 2004; Schwarzschild, 2008):

(14)   a.   Juno is fast enough to win the race.
            *Juno is as fast as she must be to make winning the race possible.*
       b.   Juno is too slow to win the race.
            *Juno is slower than she can be for winning the race to be possible.*

Following von Stechow et al. (2004):

- *enough* is an equative (*as* ADJ *as*) with a universal modal
- *too* is a comparative (*more* ADJ *than*) with an existential modal
- *enough* and *too* are duals
- gradable adjectives relate individuals and degrees on a scale

(15)   a.   $[\![\text{enough}]\!]^w :=$
            $\lambda Q_{est}\lambda P_{dest}\lambda x_e.\{d : \forall w' \in \text{ACC}(w)[Q(x)(w') \to P(d)(x)(w')]\} \subseteq \{d : P(d)(x)(w)\}$
       b.   $[\![\text{too}]\!]^w :=$
            $\lambda Q_{est}\lambda P_{dest}\lambda x_e.\{d : \exists w' \in \text{ACC}(w)[Q(x)(w') \,\&\, P(d)(x)(w')]\} \subset \{d : P(d)(x)(w)\}$

(16)   $[\![\text{fast}]\!]^w := \lambda d\lambda x.\text{SPEED}(x)(w) \geq d$

(17)   a.   Juno be fast enough to win the race
       b.   $\{d : \forall w' \in \text{ACC}(w)[\text{win}(j)(w') \to \text{SPEED}(j)(w') \geq d]\} \subseteq \{d : \text{SPEED}(j)(w) \geq d\}$
       c.   *Juno's maximal degree of speed is at least as great as the maximum degree of speed that she has in every world where she wins (i.e. the minimal speed such that there is a world in which she wins)*

This leads to a **necessity presupposition**:

- if it is impossible for Juno to win the race, (14a) and (14b) should be infelicitous
- we presuppose that there is some accessible world in which Juno wins the race

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(18)   $\exists w' \in \text{ACC}(w) : Q(x)(w')$

- from this it follows logically that the set of degrees of Juno's speed in every world where she wins is nonempty
- ...and that there is a minimum degree $d_{\text{nec}}$ which makes it possible for Juno to win:

(19)   $\exists d_{\text{nec}} : \forall w' \in \text{ACC}(w)[\text{ADJ}(x)(w') < d_{\text{nec}} \rightarrow \neg Q(x)(w')]$

With this semantics:

- *enough* and *too* are duals (von Stechow et al., 2004)
- deontic E&T constructions do not entail their complements:

(20)   a. Juno was old enough to drink.                                    $\nvdash$ *Juno drank*
        *Juno's age was at least as great as the age she has in some world where she drinks legally.*

      b. Juno was not old enough to drink.                           $\nvdash$ *Juno did not drink*
        *Juno's age was strictly less than the age she has in any legal-drinking world.*

- in fact, positive *enough* constructions never entail their complements:

(21)   Juno was fast enough to win the race.                        $\nvdash$ *Juno won the race*
      *Juno's speed was at least as great as the speed she has in some race-winning world.*

(22)   Juno was tall enough to reach the branch          $\nvdash$ *Juno reached the branch*
      *Juno's height was at least as great as the height she has in some branch-reaching world.*

- **problem:** because circumstantial accessibility relations are reflexive, negative *enough* constructions *do* entail.

(23)   Juno was not fast enough to win the race.         $\vdash$ *Juno did not win the race.*
      *Juno's speed was strictly less than the speed she has in any race-winning world.*

(24)   Juno was not tall enough to reach the branch.       $\vdash$ *Juno did not reach ...*
      *Juno's height was strictly less than the height she has in any branch-reaching world.*

## 3.3   Aspectual contrast: adding sufficiency

**Hacquard (2005):** given the perfective facts, treat E&T constructions as **underlyingly entailing**.

(11)   a. *Juno a été assez rapide pour gagner la course, #mais elle n'a pas gagné.*
        Juno was-pfv fast enough to win the race, #but she did not win.

      b. *Juno n'a été pas assez rapide pour gagner la course, #mais elle a gagné.*
        Juno was-pfv not fast enough to win the race, #but she won.

- we already have the negative entailments (23)-(24)
- to get the positive entailment, we need a sufficiency condition to be met, as well as a necessity condition
- Hacquard sets $d_{\text{suff}} = d_{\text{nec}}$:

  (25)  $\iota d : \forall w' \in \text{ACC}(w)[Q(x)(w') \leftrightarrow P(d)(x)(w')]$

- this produces the desired entailment, as long as $\text{ACC}(w)$ is reflexive:

  (26)  $[\![\text{enough}]\!]^w := \lambda Q \lambda P \lambda x.P(\iota d : \forall w' \in \text{ACC}(w)[Q(x)(w') \leftrightarrow P(d)(x)(w')])(x)(w)$

  (27)  Juno be fast enough to win the race
  $\equiv \text{SPEED}(j)(w) \geq (\iota d : \forall w' \in \text{ACC}(w)[\text{win}(j)(w') \leftrightarrow \text{SPEED}(j)(w') \geq d])$
  **entails:** $\forall w' \in \text{ACC}(w)[win(j)(w')]$

- the reflexivity requirement will (ordinarily) rule out entailment in deontic E&T


**Problem:** how do we avoid complement entailments in the imperfective (and in English)?

(10)  a. *Juno était assez rapide pour gagner la course, mais elle n'a jamais gagné.*
       Juno was-impf fast enough to win the race, but she never won.

  b. *Juno n'était pas assez rapide pour gagner la course, mais elle a toujours gagné.*
       Juno was-impf not fast enough to win the race, but she always won.

- Bhatt (1999): the imperfective is associated with a genericity operator, GEN, which does not require a witness

  (28)  Jane handles$_{\text{GEN}}$ the mail from Antarctica.
       *can be true if there has never been mail from Antarctica*

- Hacquard: GEN quantifies over 'normal' worlds which satisfy presupposition (25)

  (29)  $[\![\text{GEN}]\!]^w := \lambda Q_{st}[\forall w' \in \text{NORM}(w)Q(w')]$

  (30)  GEN(Juno be fast enough to win the race)
  $\equiv \forall w \in \text{NORM}(w^*)[(\iota d : \text{win}(j)(w) \leftrightarrow \text{SPEED}(j)(w)) \rightarrow \text{SPEED}(j)(w) \geq d]$

- the necessary and sufficient condition is met in all worlds where there *is* such a condition, but the real world need not be one of these


On Hacquard's analysis:

- E&T constructions are true implicatives, *à la* Karttunen (1971):
    - **presuppose** a necessary and sufficient condition for their complements
    - **assert** that this condition was met
- **problem:** we are left with the **distributional puzzle.** E&T complement inferences do not always pattern with implicative inferences:

- if GEN lifts the witness requirement for E&T constructions, we would expect it to do the same for implicatives:

   (31)   GEN(Juno manage to win the race)
       $\forall w' \in \text{NORM}(w)[\exists Q_{set} : [Q(j)(w') \leftrightarrow \text{win-race}(j)(w')] \rightarrow Q(j)(w')]$

- but implicatives *do* entail under the imperfective (and in English):

   (32)   *Juno réussissait à gagner la course, #mais elle n'a jamais gagné.*
       Juno managed-impf to win the race, #but she didn't win.

## 3.4   The sufficiency problem

Hacquard's suggestion in (25) sets up an equivalence between having a particular degree ($d_{\text{nec}}$) of ADJ and realizing the complement proposition – but is this what we want?

- for deontic E&T, (25) is too strong:

   (5a)   Juno was old enough to drink.
       presupposes: $\iota d : \forall w \in \text{DEON}(w^*)[\text{drink}(j)(w) \leftrightarrow \text{AGE}_w(j) \geq d]$

    – assume DEON picks out worlds where the relevant laws are like ours, and are not violated
    – (25) can be satisfied in two ways: either the only thing holding Juno back from drinking is the legal question, or there is a law that mandates that one drinks on reaching a certain age
    – so, (5a) should be infelicitous in any case where Juno does not actually drink!

      (12)   *Juno a été assez grande pour boire de l'alcool, mais elle n'a l'a jamais bu.*
          Juno was-PFV old enough to drink alcohol, but she never drank it.'

- for circumstantial E&T, it doesn't distinguish between passive and active properties
- with passive properties, it gives us the unwanted positive entailment:

   (13b)  *Juno a été assez grande pour toucher la branche.*             ($\not\vdash$)
        Juno was-pfv tall enough to touch the branch.
        Hacquard (2005): *Juno had the degree of height necessary and sufficient for her to touch the branch.*

- for exercisable capacities, it is intuitively wrong!

   (33)   *Juno a été assez rapide pour gagner la course.*
       presupposes: $\iota d : \forall w \in \text{CIRC}(w^*)[\text{win}(J)(w) \leftrightarrow \text{SPEED}_w(J) \geq d]$

    – *being d-fast* involves having the capacity to do things at speed $d$ or higher, but does not require an *action*
    – intuitively, there should be no speed that satisfies the equivalence presupposition
    – in order to entail, E&T constructions should need to force a performance/manifestation of the capacity they describe

**Preliminary proposal:** the sufficiency in (25) is not the right kind of sufficiency

- if $A$ is deontically/legally sufficient for $B$, it does not make $B$ happen
- if $A$ is **causally sufficient** for $B$, it does make $B$ happen
- when ADJ represents an exercisable capacity, we presuppose that exercising this capacity is causally sufficient for $B$

# 4 Causality in E&T constructions

**Proposal:**

Let $S$ be a proposition of the form $S = x$ *be* ADJ *enough to* $Q$, where $x$ is an individual, ADJ a relation between individuals and degrees, and $Q$ a property of individuals. Evaluated with respect to a world $w$:

(I) $S$ presupposes a degree $d_{\text{nec}}$ that is necessary for the possibility of $Q(x)$:

$$\exists d_{\text{nec}} : \forall w' \in \text{ACC}(w)[\text{ADJ}(x)(w') < d_{\text{nec}} \rightarrow \neg Q(x)(w')]$$

(II) $S$ asserts that $x$ has least $d_{\text{nec}}$ of ADJ in $w$:

$$[\![S]\!]^w = \text{ADJ}(x)(w) \geq d_{\text{nec}}$$

(III) When ADJ represents an exercisable capacity, $S$ backgrounds:

$$\forall w' \in \text{ACC}(w)[\text{DO-ADJ}(x)(d_{\text{nec}})(w') \triangleright_{\text{CAUS}} Q(x)(w')]$$

where $\text{DO-ADJ}(x)(d)(w)$ is a manifestation of $d$-ADJ by $x$ in $w$, and $\triangleright_{\text{CAUS}}$ is the causal sufficiency operator.

## 4.1 Karttunen's puzzle: modal flavour and adjective type

**Modal flavour:**

- deontic E&T constructions only presuppose necessity, so there is no entailment:

(20)  a. Juno was old enough to drink. $\nvdash$ *Juno drank*
*Juno's age was at least as great as the age she has in some world where she drinks legally.*

  b. Juno was not old enough to drink. $\nvdash$ *Juno did not drink*
*Juno's age was strictly less than the age she has in any legal-drinking world.*

- since we neither assume that people typically exercise their legal rights, nor that they never break the law, there is no systematic implicature either

**Adjective type:**

- passive properties only presuppose a necessary condition; we avoid entailment in the negative *enough* cases by invoking GEN
- exercisable capacities come along with a causal sufficiency presupposition, which is activated by a manifestation of the capacity:
    - English capacity attributions are systematically ambiguous:

        (34)  Juno was fast.
        $\rightarrow$ *eventive:* Juno did (something) fast/quickly.
        $\rightarrow$ *stative:* Juno had the capacity do (something) fast/quickly.

    - contexts privileging the eventive reading (defeasibly) activate the E&T sufficiency condition

## 4.2   Hacquard's puzzle: aspectual coercion

- perfective aspect selects for the eventive interpretation of an exercisable capacity, activating the sufficiency condition:
    - the radical, ADJ$(x)(d)$, is a stative predicate of events
    - perfective aspect selects for eventive predicates (Dowty, 1986): it combines with statives via **aspectual coercion** (Moens & Steedman, 1988; de Swart, 1998)

        (35)  *Jupiter a aimé Europa.*             $\rightarrow$ *Jupiter fell in love with Europa.*
        'Jupiter loved-PFV Europa.'                   INCHOATIVE coercion

    - Homer (2011) identifies a type of **actualistic** coercion:

        (36)  *Jean a eu du tact.*                      $\rightarrow$ *Jean acted tactfully.*
        'Jean had-PFV tact.'                            ACTUALISTIC coercion

    - actualistic coercion returns a (pragmatically-determined) eventive predicate which coincides temporally with an event in the denotation of the original stative
    - exercisable capacities are prime candidates for actualistic coercion:

        (11a)  *Juno a été assez rapide pour gagner la course.*
        'Juno was-pfv fast enough to win the race.'
        *Juno did something salient (ran) at a speed of at least $d_{nec}$*

    - perfective entails a manifestation of the capacity, producing the complement entailment
    - when we privilege a different type of coercion, the entailment disappears:

        (37)  *Juno a soudain été assez rapide pour gagner la course*
        'Juno suddenly was-pfv fast enough to win the race.'

- under negation, perfective aspect entails a manifestation of less than $d_{\text{nec}}$, precluding the possibility of realizing the complement:

(11b) *Juno n'a été pas assez rapide pour gagner la course.*     ⊢ *Juno did not win.*
      'Juno was-pfv not fast enough to win the race.'
      *Juno ran at a speed lower than $d_{nec}$*

- imperfective aspect can have either a generic (GEN) or progressive (PROG) reading:
  - GEN lifts the witness requirement by failing to enforce a manifestation at race time: either Juno's speed was not measured by a specific race-time performance (a latent capacity), or each race event represents an abnormal situation

    (10a) *Juno était assez rapide pour gagner la course ...*
          'Juno was-impf fast enough to win the race, ...'

                                                            ... but she did not participate.
                          ... but something unexpected always happened, and she never won.

  - PROG selects for eventive predicates: actualistic coercion returns an ongoing event of Juno manifesting speed $d_{nec}$. As per the **imperfective paradox**, this event can be interrupted:

    (38) Juno was baking a cake                          ⊬ *Juno baked a cake.*

- in the negative imperfective case:
  - with GEN, any (or all) winning instances are interpreted as abnormal (better with *en fait* or *vraiment*):

    (10b) *Juno n'était pas assez rapide pour gagner la course, mais elle a toujours gagné.*
          'Juno was not fast enough to win the race, but she always won.'

  - with PROG, a manifestation of less than $d_{nec}$ can be interrupted

## 4.3   The distributional puzzle

- the essential difference between implicatives and E&T constructions:
  - implicatives always assert that their preconditions are satisfied
  - E&T constructions in general only assert that their precondition can be satisfied

- in both cases, imperfective marking does not fully lift the witness requirement:

  (10) *Juno était assez rapide pour gagner la course, mais elle n'a jamais gagné.*
       'Juno was-impf fast enough to win the race, but she never won.'

  (32) *Juno réussissait à gagner la course, #mais elle n'a jamais gagné.*
       'Juno managed-impf to win the race, #but she never won.'

  - if Juno generally manages to win the race, we can deny any particular instance of winning, but not all of them – this would remove evidence of her ability
  - if Juno is generally fast enough to win the race, it is still possible that something untoward happened each time she tried, or that the requisite speed was measured/evidenced in another way

# 5   Outlook

**Open issues:**

- What about predicates like *clever*?
    - these predicates participate in implicative and non-implicative E&T constructions
    - they are interpretable as active or as individual-level properties
    - a preliminary observation: non-implicative *clever* E&T seem to involve stative complements

        (39)   John was clever enough to be a regent.                   $\not\leadsto$ *John was a regent.*

- Marques (2012) points out that perfective aspect is not enough to ensure complement entailment: temporal overlap is also required

    (40)   *No último encontro, ele foi humilhado o suficiente para agora recusar o convite para um novo encontro (mas parece que já se esqueceu, porque está a pensar aceitar.)*
    'In the last meeting, he was-PFV humiliated enough to now refuse the invitation for a new meeting (but it appears that he already forgot, since he is planning to accept).'

- this suggests that the matrix assertion and the complement need to come together into an *accomplishment*-like structure: a process culminating in a punctual event
- complement-entailing E&T constructions seem to be about **dispositions** and **abilities**

**Looking ahead:**

- E&T constructions do not simply establish the possibility of their complements, but rather the possibility of an action which guarantees the realization of their complements: they are hypothetical guarantees
- this suggests a route forward in the analysis of **actuality entailments** (Bhatt, 1999):

    (41)   a.   *Olga a pu soulever un frigo, #mais elle ne l'a pas fait.*
             'Olga can-pfv lift a fridge, #but she did not do it.'
           b.   *Olga pouvait soulever un frigo, mais elle ne l'a jamais fait.*
             'Olga can-impf lift a fridge, but she never did it.'

    - represent abilities (in ability modals) like exercisable capacities: as potentials for some action with the result specified in the modal complement

- the 'moving pieces' in the E&T puzzles give us a view on the essential features of the actuality entailment picture

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