Mandarin Has Degree Abstraction After All

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Degree abstraction

A configuration at LF in which there is a trace of type $d$ that is bound by a lambda abstraction operator.

$$\lambda d \quad \cdots \quad d \quad \cdots$$
Degree abstraction as a parameter (Beck et al. 2010)

- Degree Semantics Parameter (DSP) whether or not the language has gradable predicates with degree slots
- Degree Abstraction Parameter (DAP) whether or not the language has degree abstraction
Degree abstraction as a parameter (Beck et al. 2010)

- Degree Semantics Parameter (DSP) whether or not the language has gradable predicates with degree slots
- Degree Abstraction Parameter (DAP) whether or not the language has degree abstraction

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<td>Mandarin</td>
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<td>(also Krasikova 2008, Erlewine 2018)</td>
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Putative diagnostics for determining whether a language has degree abstraction (Krasikova 2008, Beck et al. 2004, 2010):

1. Degree questions
2. Subcomparatives
3. Scope interactions between degree quantifiers and modals
4. Negative island effects

For Mandarin, Erlewine (2018) adds:

6. Attributive comparatives
7. Comparatives with embedding in standard clauses
Degree questions

\[ \lambda d . \text{height}(a) \geq d \]

\[ \text{how}_d \]

\[ \text{height}(a) \geq d \]

\[ \text{tall} \]

\[ \text{Captain Apollo} \]

\[ \lambda x . \text{height}(x) \geq d \]

\[ \text{et} \]

\[ \text{is} \]

\[ \lambda x . \text{height}(x) \geq d \]

\[ \text{et} \]

\[ d \]

\[ \lambda d \lambda x . \text{height}(x) \geq d \]

\[ d \]

\[ \langle d, \text{et} \rangle \]

\[ t_d \]

\[ \text{tall} \]
Degree questions in Mandarin

Beck et al. (2010): Mandarin lacks degree questions (⇒ [−DAP]).

(1) *John shi duo gao?
    John COP how tall
    ‘How tall is John?’
Degree questions in Mandarin

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(1) *John $\text{shi}$ duo gao?

John $\text{COP}$ how tall

‘How tall is John?’

But actually it’s fine without $\text{shi}$:

(2) John duo gao?

John how tall

‘How tall is John?’
Degree questions in Mandarin

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(1) *John shi duo gao?
    John COP how tall
    ‘How tall is John?’

But actually it’s fine without shi:

(2) John duo gao?
    John how tall
    ‘How tall is John?’

Erlewine (2018:23): “Mandarin Chinese is a wh-in-situ language and its degree questions are not subject to syntactic islands (Tsai 1994; Liao 2013), suggesting that movement is not involved.”
Subcomparatives

(3) The tree is taller than the pool is deep.

\[
\max(\lambda d \cdot \text{height}(t) \geq d) > \max(\lambda d' \cdot \text{depth}(p) \geq d')
\]

\[
\lambda D_2 \cdot \max(D_2) > \max(\lambda d' \cdot \text{depth}(p) \geq d')
\]

\[
\langle dt, t \rangle \lambda D_1 \lambda D_2 \cdot \max(D_2) > \max(D_1)
\]

\[
\lambda d' \cdot \text{depth}(p) \geq d'
\]

\[
| dt, \langle dt, t \rangle | \text{er}
\]

\[
\lambda d \text{ the tree is } d \text{ tall}
\]

\[
| dt | \text{than } \lambda d' \text{ the pool is } d' \text{ deep}
\]
No subcomparatives in Mandarin

(4)  

a. men bi zhuozi kuan.  
door than table wide  
‘The door is wider than the table.’

b. *men kuan bi zhuozi chang.  
door wide than table long  
‘The door is wider than the table is long.’
No subcomparatives in Mandarin

(4)  a. men bi zhuozi kuan.
    door than table wide
    ‘The door is wider than the table.’

  b. *men kuan bi zhuozi chang.
    door wide than table long
    ‘The door is wider than the table is long.’

Krasikova (2008) and Beck et al. (2010): ⇒ [−DAP]
Erlewine’s analysis

Erlewine (2018): Mandarin is [−DAP], but that's not why subcomparatives are disallowed.
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Erlewine (2018): Mandarin is [−DAP], but that’s not why subcomparatives are disallowed.

**Erlewine’s deletion constraint**: In Mandarin $bi$-comparatives, a matching ‘local predicate’ must be deleted.
Erlewine’s analysis

Erlewine (2018): Mandarin is [−DAP], but that's not why subcomparatives are disallowed.

**Erlewine’s deletion constraint:** In Mandarin *bi*-comparatives, a matching ‘local predicate’ must be deleted.

(5) door [wide] [ than table {wide, *long}].
Erlewine’s analysis

Erlewine (2018): Mandarin is $[-\text{DAP}]$, but that's not why subcomparatives are disallowed.

**Erlewine’s deletion constraint:** In Mandarin *bi*-comparatives, a matching ‘local predicate’ must be deleted.

\[(5) \text{ door [wide] [ than table \{wide, *long\}].}\]

If this constraint holds, Mandarin might as well be $[+\text{DAP}]$. 

Subequatives in Mandarin

Although subcomparatives are not possible, ‘subequatives’ are:

(6) ni neng pao duo kuai, wo jiu neng pao duo kuai.
you can run how fast, I then can run how fast
‘I can run as fast as you can.’

 Analyzed as “wh-correlatives”, with wh-movement (Chen 2019):
Degree quantifiers (Heim 2000)

\[
\langle et, t \rangle \quad et \quad \langle dt, t \rangle
\]

- every astronaut
- -er than 6 feet

\[
\lambda x \quad \text{Mary} \quad \text{knows} \quad x
\]

\[
\lambda d \quad \text{Mary} \quad \text{is} \quad d\text{-tall}
\]
Degree quantifiers (Heim 2000)

How would we tell? Scope ambiguities. Often missing (Kennedy 1997). Also, often the two scope readings collapse (Heim 2000).

Exceptions:

- *less* comparatives (e.g. *required to be 5pp less long than that*)
- *exactly* differentials (e.g. *required to be exactly 5pp longer than that*)
- comparative ellipsis (e.g. *Mary needs to drive faster than John*)
Comparative ellipsis

(7) Mary needs to drive faster than John. (Heim 2000)

\[ \text{need} > \text{-er:} \]
\[ \text{needs } [ \text{-er than } \lambda d \text{ John drive } d \text{-fast } ] \lambda d \text{ Mary to drive } d \text{-fast} \]
‘It is required that Mary drives faster than John drives’

\[ \text{-er} > \text{need:} \]
\[ [ \text{-er than } \lambda d \text{ needs John drive } d \text{-fast } ] \lambda d \text{ needs Mary drive } d \text{-fast} \]
\[ \text{max}(\lambda d . j \text{ needs to drive } d \text{-fast}) < \text{max}(\lambda d . m \text{ needs to drive } d \text{-fast}) \]
‘Mary’s minimum required speed is above John’s minimum required speed’
Comparative ellipsis

(7) Mary needs to drive faster than John. (Heim 2000)

*need* $>$ *-er:*

needs $\lambda d$ John drive $d$-fast $\exists \lambda d$ Mary to drive $d$-fast

‘It is required that Mary drives faster than John drives’

*-er* $>$ *need:*

$\exists \lambda d$ needs John drive $d$-fast $\exists \lambda d$ needs Mary drive $d$-fast

max($\lambda d \cdot j$ needs to drive $d$-fast) $<$ max($\lambda d \cdot m$ needs to drive $d$-fast)

‘Mary’s minimum required speed is above John’s minimum required speed’

Context for er $>$ need:

John and Mary need to get to Boston by 8.

Mary is in New Haven; John is in Providence.
Comparative ellipsis with negative antonyms

(8) a. John needs to drive less fast than Mary.
    b. John needs to drive slower than Mary. (Heim 2006)

less > need:
[ less than $\lambda d \text{ needs Mary drive } d\text{-fast} \ ] \lambda d \text{ needs John drive } d\text{-fast} \\
max(\lambda d . j \text{ needs to drive } d\text{-fast}) < max(\lambda d . m \text{ needs to drive } d\text{-fast})
‘John’s minimum required speed is below Mary’s minimum required speed’

-er > need > slow:
[ er than $\lambda d \text{ needs Mary drive } d\text{-slow} \ ] \lambda d \text{ needs John drive } d\text{-slow} \\
min(\lambda d . j \text{ needs to drive } d\text{-slow}) < min(\lambda d . m \text{ needs to drive } d\text{-slow})
‘John’s maximum allowed speed is below Mary’s maximum allowed speed’
Scope interactions in Mandarin

Krasikova (2008):

(9) John xuyao [ bi Bill ] shao mai yixie lazhu.
    John must [ than Bill ] little buy some candles
    ‘John must buy fewer candles than Bill.’

must > less
It is required that John buys fewer candles than Bill.

less > must
#John’s minimally required amount is below Bill’s.
Scope interactions in Mandarin

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    John must [ than Bill ] little buy some candles 
    ‘John must buy fewer candles than Bill.’

\textit{must} > \textit{less} \\
It is required that John buys fewer candles than Bill.

\textit{less} > \textit{must} \\
#John’s minimally required amount is below Bill’s.

\textit{-er} > \textit{must} > \textit{little} \\
John’s maximum amount allowed is below Bill’s. (available?)
Comparison-of-maxima reading in Mandarin

Context:
The speed limit on I-90 is 60 mph; the speed limit on I-95 is 80 mph.

(10) ni zai I-90 xuyao [ bi zai I-95 ] kai de man.
    you on I-90 need [ than on I-95 ] drive DE slow
    ‘You need to drive more slowly on I-90 than on I-95.’

\[
er > need > slow:
\min (\lambda d \ . \ \square \ you \ drive \ d \text{-slow} \ on \ I90) < \min (\lambda d \ . \ \square \ you \ drive \ d \text{-slow} \ on \ I95)
\]
‘The max OK speed on I-90 is below the max OK speed on I-95’

True even if driving 50 mph on I-90 but 40 mph on I-95 is OK.
Embedding in standard

(11) Mary is happier than Bill thinks she is happy.
\[ \max(\lambda d . \text{Mary is } d\text{-happy}) > \max(\lambda d' . \text{Bill thinks Mary is } d'\text{-happy}) \]

(12) John thinks Mary is happier than Bill thinks she is happy.
\[ \max(\lambda d . \text{John thinks Mary is } d\text{-happy}) > \max(\lambda d' . \text{Bill thinks Mary is } d'\text{-happy}) \]
Embedding in standard

(11) Mary is happier than Bill thinks she is happy.
    \[
    \max(\lambda d . \text{Mary is } d\text{-happy}) > \max(\lambda d' . \text{Bill thinks Mary is } d'\text{-happy})
    \]

(12) John thinks Mary is happier than Bill thinks she is happy.
    \[
    \max(\lambda d . \text{John thinks Mary is } d\text{-happy}) > \max(\lambda d' . \text{Bill thinks Mary is } d'\text{-happy})
    \]
Embedding in standard

Erlewine (2018):

(13) \([_{TP1} \text{Mary } kaoxin] \text{ bi } [{_{TP2} \text{John } kaoxin}].\)

Mary happy than John happy
‘Mary is happier than John.’
Embedding in standard

Erlewine (2018):

(13) \[[\text{TP}_1 \text{Mary } \text{kaixin}] \text{ bi } [\text{TP}_2 \text{John } \text{kaixin}].
\]
Mary happy than John happy
‘Mary is happier than John.’

(14) \[^{*} [\text{TP}_1 \text{Mary } \text{kaixin}] \text{ bi } [\text{TP}_2 \text{John } \text{juede } [\text{ta } \text{kaixin}]].
\]
Mary happy than John think she happy
‘Mary is happier than John thinks she is.’
Embedding in standard

Erlewine (2018):

(13) \([_{TP1} \text{Mary } \text{kaixin}] \text{ bi } [_{TP2} \text{John } \text{kaixin}].\)
    Mary happy than John happy
    ‘Mary is happier than John.’

(14) \(*[_{TP1} \text{Mary } \text{kaixin}] \text{ bi } [_{TP2} \text{John } \text{jude} [\text{ta } \text{kaixin}]].\)
    Mary happy than John think she happy
    ‘Mary is happier than John thinks she is.’

(15) \(*[_{TP1} \text{John } \text{jude} \text{Mary kaixin}] \text{ bi } [_{TP2} \text{Bill } \text{jude} \text{Mary kaixin}].\)
    John think Mary happy than Bill think Mary happy
    ‘John thinks Mary is happier than Bill thinks she is.’
Embedding in standard

Erlewine (2018):

(13) \([TP_1 \text{Mary} \ kaixin] \ bi \ [TP_2 \text{John} \ kaixin]\).

Mary happy than John happy

‘Mary is happier than John.’

(14) \(*[TP_1 \text{Mary} \ kaixin] \ bi \ [TP_2 \text{John} \ juede \ [ta \ kaixin]].\)

Mary happy than John think she happy

‘Mary is happier than John thinks she is.’

(15) \(*[TP_1 \text{John} \ juede \ Mary \ kaixin] \ bi \ [TP_2 \text{Bill} \ juede \ Mary \ kaixin].\)

John think Mary happy than Bill think Mary happy

‘John thinks Mary is happier than Bill thinks she is.’

Erlewine (2018): (15) bad ⇒ \([-\text{DAP}]\)
A closer look

Contrast between *think* and *make*:

(16) * John bi Bill juede Mary kaixin.
    John than Bill think Mary happy
    ‘John thinks Mary is happier than Bill thinks she is.’

(17)  John bi Bill ling Mary kaixin.
    John than Bill make Mary happy
    ‘John makes Mary happier than Bill does.’
A closer look

Contrast between *think* and *make*:

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      John than Bill think Mary happy
      ‘John thinks Mary is happier than Bill thinks she is.’

(17)  John bi Bill ling Mary kaixin.
      John than Bill make Mary happy
      ‘John makes Mary happier than Bill does.’

Revising the deletion requirement:

(18)  a.  *John [VP think [TP Mary happy]] than Bill think Mary happy.
     b.  John [VP make [SC Mary happy]] than Bill make Mary happy.
A closer look

Contrast between *think* and *make*:

(16) * John bi Bill juede Mary kaixin.
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    ‘John thinks Mary is happier than Bill thinks she is.’

(17) John bi Bill ling Mary kaixin.
    John than Bill make Mary happy
    ‘John makes Mary happier than Bill does.’

Revising the deletion requirement:

(18) a. *John [VP think [TP Mary happy]] than Bill think Mary happy.
    b. John [VP make [SC Mary happy]] than Bill make Mary happy.

Same in English:

(19) a. *John thinks Mary is happier than Bill does think Mary is happy.
    b. John makes Mary happier than Bill does make Mary happy.
Attributive comparatives


(20) John bought bigger apples than Bill. 
    than \([Op; [_{TP} Bill bought [_{DP} t_i big apples]]] \)
    \( \lambda d . Bill bought d\text{-big apples} \)
Attributive Comparatives in Mandarin

Erlewine (2018): Absent in Mandarin (⇒ [−DAP])

(21) *John bi Bill mai le [DP {duo, da} de pingguo].
    John than Bill buy ASP {many, big} DE apple
    ‘John bought more/bigger apples than Bill.’
Attributive Comparatives in Mandarin

Erlewine (2018): Absent in Mandarin (⇒ [−DAP])

(21) *John bi Bill mai le [DP {duo, da} de pingguo].
    John than Bill buy ASP {many, big} DE apple
    ‘John bought more/bigger apples than Bill.’

But! They can be rescued by the overt degree morpheme *geng* ‘more’:

(22) John bi Bill mai le *geng* {duo, da} de pingguo.
    John than Bill buy ASP more {many, big} DE apple
(23) In Mandarin, the direct complement to T(ense) must either be (an extended projection of) verb or functional morpheme that can in principle combine with a verb.
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The structure of prenominal modifiers as RCs (Grano 2012):

\[
\begin{array}{c}
\text{DP} \\
\text{RC} \quad \text{NP} \\
\text{TP} \quad \text{de} \\
\text{T} \quad \text{DegP} \\
\text{Deg} \quad \text{AP} \\
\text{hen} \quad \text{‘very’} \\
\text{geng} \quad \text{‘more’} \\
\text{big}
\end{array}
\]
Negative island effects

(24) #John bought a more expensive book than Bill didn’t buy.
Negative island effects

(24) #John bought a more expensive book than Bill didn’t buy.

Why anomalous?
Negative island effects

(24) #John bought a more expensive book than Bill didn’t buy.

Why anomalous?

The set of degrees formed through degree abstraction in the than-clause can be characterized as follows:

(25) $\lambda d . \text{Bill didn’t buy a } d\text{-expensive book}$
Negative island effects

(24)  #John bought a more expensive book than Bill didn’t buy.

Why anomalous?
The set of degrees formed through degree abstraction in the *than*-clause can be characterized as follows:

(25)  $\lambda d . \text{Bill didn’t buy a } d\text{-expensive book}$

Comparatives are thought to involve a maximization operation over this set of degrees:

(26)  $\text{max}(\lambda d . \text{Bill didn’t buy a } d\text{-expensive book})$
Negative island effects

(24) #John bought a more expensive book than Bill didn’t buy.

Why anomalous?

The set of degrees formed through degree abstraction in the than-clause can be characterized as follows:

(25) λd . Bill didn’t buy a d-expensive book

Comparatives are thought to involve a maximization operation over this set of degrees:

(26) max(λd . Bill didn’t buy a d-expensive book)

Problem: there is no maximum degree d such that Bill didn’t buy a d-expensive book.
Negative island effects in Mandarin

(27) \[\text{DP}_{\text{RC}} \text{ John mai de} \text{ shu}] \text{ bi} \ [\text{DP}_{\text{RC}} \text{ Bill mei mai de} \text{ shu}] \text{ gui.}

John buy DE book than Bill NEG buy DE book expensive
‘The book John bought is more expensive than the book Bill didn’t buy.’
Negative island effects in Mandarin

(27) \[\text{DP}_{[\text{RC } \text{John mai de}]} \text{ shu]} \text{ bi } \text{DP}_{[\text{RC } \text{Bill mei mai de}]} \text{ shu]} \text{ gui.} \]

John buy DE book than Bill NEG buy DE book expensive

‘The book John bought is more expensive than the book Bill didn’t buy.’

• Krasikova (2008), Beck et al. (2010): \( \Rightarrow \text{[−DAP]} \)
Negative island effects in Mandarin

(27) \([\text{DP}_{\text{RC}} \text{John mai de]} \text{shu}] \text{ bi } [\text{DP}_{\text{RC}} \text{Bill mei mai de]} \text{shu}] \text{ gui.}

John buy DE book than Bill NEG buy DE book expensive
‘The book John bought is more expensive than the book Bill didn’t buy.’

• Krasikova (2008), Beck et al. (2010): ⇒ [−DAP]

• This example involves a definite description of a book
\(\lambda d\). the book which Bill didn’t buy is \(d\)-expensive
Negative island effects in Mandarin

(27) \([\text{DP}_{\text{RC}} \text{John mai de]} \text{ shu} \] \text{ bi } \[\text{DP}_{\text{RC}} \text{ Bill mei mai de]} \text{ shu} \] \text{ gui.} \\
John buy \text{ DE book than } \text{ Bill NEG buy DE book expensive} \\
‘The book John bought is more expensive than the book Bill didn’t buy.’

• Krasikova (2008), Beck et al. (2010): \(\Rightarrow [\neg \text{DAP}]\)

• This example involves a definite description of a book \(\lambda d . \text{the book which Bill didn’t buy is } d\text{-expensive}\)

• Negative island effects can be observed in Mandarin:
Negative island effects in Mandarin

    John buy DE book than Bill NEG buy DE book expensive
    ‘The book John bought is more expensive than the book Bill didn’t buy.’

- Krasikova (2008), Beck et al. (2010): ⇒ [−DAP]
- This example involves a definite description of a book
  \(\lambda d . \text{the book which Bill didn’t buy is } d\)-expensive
- Negative island effects can be observed in Mandarin:

(28) John bi Bill (♯ mei) pao de kuai.
    John than Bill NEG run DE fast
    ‘John runs faster than Bill doesn’t run.’
Reconsider negative island effects

Suppose ‘John bought a more expensive book than Bill didn’t buy’ can mean ‘John bought a more expensive book than the one Bill didn’t buy’.
Reconsider negative island effects

Suppose ‘John bought a more expensive book than Bill didn’t buy’ can mean ‘John bought a more expensive book than the one Bill didn’t buy’.

Could this reading be predicted from [−DAP]? No.
Reconsider negative island effects

Suppose ‘John bought a more expensive book than Bill didn’t buy’ can mean ‘John bought a more expensive book than the one Bill didn’t buy’.

Could this reading be predicted from [−DAP]? No.

What sort of reading would give evidence for [−DAP]? Unclear.
Diagnostics for degree abstraction in Mandarin

1. Degree questions (yes $\nRightarrow$ DA)
2. Subcomparatives (or subequatives) (yes $\Rightarrow$ DA)
3. Scope interactions with modals (yes $\Rightarrow$ DA)
4. Embedding in standard (yes $?$ DA)
5. Attributive comparatives (yes $\Rightarrow$ DA)
6. Negative island effects (yes $\nRightarrow$ DA)
Is degree abstraction universal?

Again and again, the evidence that some languages lack degree abstraction has been called into question.
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These findings cast doubt on the Degree Abstraction Parameter.
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But they raise an interesting possibility: Is degree abstraction universal (among languages that have gradable predicates with degree slots)?
Is degree abstraction universal?

Again and again, the evidence that some languages lack degree abstraction has been called into question.

These findings cast doubt on the Degree Abstraction Parameter.

But they raise an interesting possibility: Is degree abstraction universal (among languages that have gradable predicates with degree slots)?

Support: Evidence for degree abstraction has been found in

- P’urhepecha (Zyman 2015)
- Tswefap (Clem 2019)
- two Salish languages (Davis & Mellesmoen 2019)


Chen, Sherry Y. 2019. Deriving wh-correlatives in mandarin chinese: Wh-movement and (island) identity. In the 50th annual meeting of the north east linguistic society (nels 50), .


Island effects to show *wh*-movement in *wh*-correlatives

Coordinate Structure Constraint

(29) *zhuozi [ConjP duo kuan he 2 mi chang], men jiu duo kuan.  
    table how wide and 2 meter long door then how wide  
    Lit: ‘The table is X wide and 2 meters wide, and the door is that wide.’

Left Branch Condition

(30) *ta you yi ge [NP duo gao de xiaohai], men jiu you duo gao.  
    he has one CL how tall DE child door then be how tall  
    Lit: ‘He has a X tall child, and the door is that tall.’
exactly-differentials

(31) lunwe yaoqiu bi zhe pian caogao duo qiahao 2 ye. paper require than this CL draft more exactly 2 page ‘The paper must be exactly 2 pages longer than this draft.’
exactly-differentials

(31) lunwe yaoqiu bi zhe pian caogao duo qiahao 2 ye. paper require than this CL draft more exactly 2 page ‘The paper must be exactly 2 pages longer than this draft.’

✓ Context: The draft is 10pp. The paper must be $= 12pp$.

(need $> -er$)

[ require [ exactly 2pp -er than 10pp ] [ 1 [ the paper be t1 long ] ] ]

$\square \max(\lambda d . \text{length}(\text{the-paper}, d) = 12pp)$
exactly-differentials

(31) lunwe yaoqiu bi zhe pian caogao duo qiahao 2 ye.
    paper require than this CL draft more exactly 2 page
    ‘The paper must be exactly 2 pages longer than this draft.’

✓ Context: The draft is 10pp. The paper must be = 12pp.
  (need > -er)
  [ require [ exactly 2pp -er than 10pp ] [ 1 [ the paper be t₁ long ] ] ]
  □ max(λd . length(the-paper, d) = 12pp)

✓ Context: The draft is 10pp. The paper must be ≥ 12pp.
  (-er > need)
  [ exactly 2pp -er than 10pp ] [ 1 [ need [ the paper be t₁ long ] ] ]
  max(λd . □length(the-paper, d) = 12pp)
Lexical entries

From (Heim 2006):

\[ \text{fast} \sim \lambda d \lambda x . \text{speed}(x) \geq d \]
‘the set of degrees \( x \)’s speed reaches or exceeds’

\[ \text{slow} \sim \lambda d \lambda x . \text{speed}(x) < d \]
‘the set of degrees \( x \)’s speed does NOT reach’

\[ \text{-er} \sim \lambda S_{dt} \lambda M_{dt} . S \subset M \]
‘\( \max(M) > \max(S) \) for positive; \( \min(M) < \min(S) \) for negative’

\[ \text{less} \sim \lambda S_{dt} \lambda M_{dt} . M \subset S \]
‘\( \max(M) < \max(S) \) for positive; \( \min(M) > \min(S) \) for negative’
less fast

(32) John needs to drive less fast than Mary.

\[ \lambda d . \Box \text{speed}(j) \geq d \subseteq \lambda d' . \Box \text{speed}(m) \geq d' \]
less fast

(32) John needs to drive less fast than Mary.

\[
\lambda d . \square \text{speed}(j) \geq d \subset \lambda d' . \square \text{speed}(m) \geq d' \\
\equiv \max(\lambda d . \square \text{speed}(j) \geq d) < \max(\lambda d' . \square \text{speed}(m) \geq d')
\]

\[
\lambda S_{dt} \lambda M_{dt} . M \subset S \quad \lambda d' . \square \text{speed}(m) \geq d' \\
\text{less} \quad \lambda d \text{ John needs to drive } d\text{-fast} \\
\text{than } \lambda d' \text{ Mary needs to drive } d'\text{-fast}
\]
(32) John needs to drive less fast than Mary.

\[ \lambda d \cdot \Box \text{speed}(j) \geq d \subset \lambda d' \cdot \Box \text{speed}(m) \geq d' \]

\[ \equiv \max(\lambda d \cdot \Box \text{speed}(j) \geq d) < \max(\lambda d' \cdot \Box \text{speed}(m) \geq d') \]

‘John’s minimum required speed is below Mary’s’

\[ \lambda S_{dt} \lambda M_{dt} . M \subset S \quad \lambda d' \cdot \Box \text{speed}(m) \geq d' \]

less

\[ \lambda d \cdot \Box \text{speed}(j) \geq d \]

\[ \equiv \max(\lambda d \cdot \Box \text{speed}(j) \geq d) < \max(\lambda d' \cdot \Box \text{speed}(m) \geq d') \]

‘John needs to drive \( d \)-fast

\[ \lambda d' \cdot \Box \text{speed}(m) \geq d' \]

than \( \lambda d' \) Mary needs to drive \( d' \)-fast
less fast: example

\[ \square \text{Speed}(j) \geq d_3 \]

\[ \square \text{Speed}(m) \geq d_4 \]
more slowly

(33) John needs to drive more slowly than Mary.

\[ \lambda d'. \Box \text{speed}(m) < d' \subset \lambda d . \Box \text{speed}(j) < d \]
more slowly

(33) John needs to drive more slowly than Mary.

\[ \lambda d' . \Box \text{speed}(m) < d' \subset \lambda d . \Box \text{speed}(j) < d \]
\[ \equiv \min(\lambda d . \Box \text{speed}(j) < d) < \min(\lambda d' . \Box \text{speed}(m)) \]
more slowly

(33) John needs to drive more slowly than Mary.

\[ \lambda d'. \square \text{speed}(m) < d' \subset \lambda d . \square \text{speed}(j) < d \]
\[ \equiv \min(\lambda d . \square \text{speed}(j) < d) < \min(\lambda d'. \square \text{speed}(m)) \]

‘John’s maximum allowed speed is below Mary’s’

\[ \lambda S_{dt} \lambda M_{dt} . S \subset M \quad \lambda d'. \square \text{speed}(m) < d' \]

\[ \lambda d \text{ John needs to drive } d \text{-slow} \]

\[ \text{than } \lambda d' \text{ Mary needs to drive } d' \text{-slow} \]
more slowly: example

\[
\begin{align*}
\text{Speed}(j) & \quad \text{Speed}(m) \\
\square \text{speed}(j) < d_4 & \quad \square \text{speed}(m) < d_5
\end{align*}
\]