Nominal Quantifiers in *than* Clauses and Degree Questions*

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Abstract

I explore interactions between nominal quantifiers and degree expressions in comparative *than* clauses and degree questions. I argue that the scopal behavior of quantifiers in degree constructions is best understood as the result of general principles governing the interactions between quantifiers and interrogative complementizers, not an ad hoc constraint on the relative scope of nominal quantifiers and degree operators (viz. the well-known but ill-understood Heim–Kennedy Constraint). Consideration of data from pair-list, functional, and single-point readings of quantifiers in degree constructions supports the view that *than* clauses should be analyzed as degree questions. The approach developed here offers a new perspective on the interactions between quantifiers and degrees, pointing us towards an explanatory account for which the Heim–Kennedy Constraint has long served as placeholder.

1 Introduction

The scopal behavior of quantifiers in comparative *than* clauses has attracted a great deal of attention in the recent literature. Such quantifiers often appear to take scope at the matrix level, despite their syntactic location within–and, consequently, their putative scopal confinement to–the subordinate finite *than* clause. This phenomenon has led to a wide variety of new proposals about the syntactic and semantic structure of *than* clauses, and these in turn have led to intriguing, if poorly understood, observations about the interactions between nominal quantification and degree operators.

One such interaction has come to be known as the Heim–Kennedy Constraint (Heim 2001, 2006, Bhatt & Pancheva 2004, Alrenga & Kennedy 2014). While specific formulations differ, the core generalization is as in (1):

(1) Heim–Kennedy Constraint (received version): A nominal quantifier is barred from taking scope between a degree quantifier and its trace.

The Heim–Kennedy Constraint restricts degree operators' scopal interactions with nominal quantifiers. It does not restrict their interactions with modals. In this connection, Nouwen & Dotlačil (2017) make some novel observations about interpretive asymmetries between wide-scoping nominal quantifiers and wide-scoping modals in *than* clauses. They conclude that nominal quantifiers must take scope at an exceptionally high position within the *than* clause, and they suggest that this invites a new and more stringent version of the Heim–Kennedy Constraint:

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(2) Heim–Kennedy Constraint (version of Nouwen & Dotlačil 2017): A nominal quantifier is barred from taking scope between a degree abstractor and the variable it binds.

Here I suggest that the high scope position occupied by nominal quantifiers in *than* clauses is the same as the one occupied by quantifiers in pair-list readings of embedded questions. Many have suggested that such quantifiers move higher than ordinary quantifier raising (QR) usually permits (Chierchia 1993, Dayal 1996, 2016, Szabolcsi 1997), and Nouwen & Dotlačil recognize that the relevant reading of the *than* clause is a pair-list reading. Rather than propose an additional layer of degree morphology in *than* clauses, as Nouwen & Dotlačil do, I take this to support the view that *than* clauses should be treated on a par with embedded questions more generally (Fleisher 2018). If the scopal behavior that we see in *than* clauses reflects this more general property of embedded questions, then it likely does not motivate the revisions to the Heim–Kennedy Constraint proposed by Nouwen & Dotlačil.

While *than* clauses and embedded questions both support pair-list readings with quantifiers (as well as single-point readings; see section 6), only the latter support functional readings. I suggest here that this is due to a selectional property of *than* itself; it thus need not trouble the claim that *than*'s clausal complement has the structure of an embedded question. Specifically, I claim that *than* needs to extract a degree from (the trace of) its complement, but the functional reading involves abstraction over functions rather than degrees, with the result that the requisite degree cannot be extracted.

The structure of the paper is as follows. In section 2, I review Nouwen & Dotlačil's observations about the extraordinarily high scope of nominal quantifiers in *than* clauses and their proposed analysis. In section 3, I discuss the parallels between *than* clauses and embedded questions (Fleisher 2018) before sketching a proposal in section 4 that treats nominal quantifiers' scope in *than* clauses on a par with that of quantifiers in pair-list readings of embedded questions. In section 5, I discuss functional readings. Section 6 concludes.

2 Nominal Scope in *than* Clauses

Scopal phenomena within the *than* clause have led many authors to rethink traditional degree-based treatments of gradable expressions and inspired a corresponding technical ingenuity in the literature. Schwarzschild & Wilkinson (2002) were the first to propose a semantics for *than* clauses based on scalar intervals rather than degrees, and much of the subsequent literature has followed their lead.[1] Of particular note is Heim (2006), who proposed a mechanism for moving between degree-based lexical entries for gradable expressions and interval-based denotations for the larger constituents in which they are found. Heim accomplishes this by introducing a "point-to-interval" operator, Π, defined in (3). (The two arguments of Π are intervals, type $\langle d,t \rangle$; the *max* operator picks out the greatest degree satisfying a particular degree property.)

(3) $[\![\Pi]\!] = \lambda D \lambda D'.max(D') \in D$

A constituent consisting of Π plus its first argument (henceforth, the "Π-phrase") forms a generalized quantifier over degrees. Heim proposes that the Π-phrase is merged in the degree argument position within the *than* clause and then raises to take scope, leaving behind a degree trace. As she

[1] In more recent work, Schwarzschild has developed a degree semantics based on scalar segments (see Schwarzschild, this volume, and references therein).

shows, certain ambiguities involving modals in *than* clauses can then be analyzed as scopal ambiguities arising from the interaction between the modal and the Π-phrase. This is sketched in (4) and (5).

(4) The paper is longer than it should be.
   a. *than*-clause LF: λ1 [□ [Π t_1] λ2 [it is t_2-long]]
   b. Semantic value: λ*D*.□(λ*w*.its length in $w \in D$)

(5) The paper is longer than it needs to be.
   a. *than*-clause LF: λ1 [[Π t_1] λ2 □ [it is t_2-long]]
   b. Semantic value: λ*D*.*max*(λ*d*.□(λ*w*.its length in $w \geq d$)) $\in D$

In (4), the *than* clause characterizes intervals *D* such that it is deontically necessary that the paper's length be contained in *D*. When composed with the matrix clause, this yields a maximum-related reading, in which we understand that the paper's actual length exceeds its length in any accessible world; in other words, the paper is too long. In (5), the *than* clause characterizes intervals *D* such that the greatest degree of length that the paper must achieve in all deontically accessible worlds is contained in *D*; this degree is the paper's minimum required length. When composed with the matrix clause, this yields a minimum-related reading, in which we understand that the paper's actual length exceeds the minimum required threshold; in other words, the paper is long enough and then some. (For further discussion of minimum- and maximum-related readings in *than* clauses, see Rullmann 1995, Krasikova 2011, Beck 2013, and Zhang & Ling 2017.)

Nouwen & Dotlačil's key observation is that nominal quantifiers in *than* clauses do not yield minimum- or maximum-related readings of this sort. This is something that we can see clearly only once we introduce a non-upward-entailing differential phrase into the matrix clause (Fleisher 2016). A sentence like (6), with universal *every*, cannot mean that John is exactly six inches taller than just the tallest girl (as would be the case on a maximum-related reading) or just the shortest girl (as on a minimum-related reading). Rather, it has only a pair-list reading, where for each girl *g*, John is exactly six inches taller than *g* is. This leads to an inference that the girls' heights are all the same.

(6) John is exactly six inches taller than every girl is.

Nouwen & Dotlačil conclude that the nominal quantifier *every girl* must take scope higher than the position where the universal modal takes scope in examples like (4). They introduce two operators above the projection where the *wh* degree or interval operator moves on standard analyses, and propose that the nominal quantifier takes scope between them. The higher of the two novel operators dynamically collects the values assigned to a designated variable introduced by the lower novel operator, one per degree returned by the *than* clause when the universal nominal quantifier scopes between them. The result is a degree plurality. (These novel operators compose vacuously when nothing takes scope between them, returning just a single *than*-clause degree. I refer the interested reader to Nouwen & Dotlačil 2017 for details, and to Dotlačil & Nouwen 2016 for a theory of how the degree plurality denoted by the *than* clause composes with the matrix clause.)

Nouwen & Dotlačil suggest that the range of readings in examples like (6) is limited because the Heim–Kennedy Constraint severely restricts the range of positions where the nominal quantifier may take scope within the *than* clause. There are two steps in the argument. First, they take the lack of a maximum-related reading to indicate that a nominal quantifier cannot take scope where the universal modal takes scope in examples like (4); as they note, this is a position that intervenes not between

a degree quantifier and its trace, but merely between a *wh* degree or interval operator and its trace. Second, they conclude that the Heim–Kennedy Constraint bars nominal quantifiers from taking scope between any degree or interval abstractor and its trace; this is their version of the Heim–Kennedy Constraint, stated above in (2). They suggest that the higher operators they introduce provide a licit scope position for the quantifier, and that the lack of ambiguity in such *than* clauses is due to this position's being the only one where the nominal quantifier can take scope.

There are at least two considerations that might lead one to question Nouwen & Dotlačil's analysis. First, the expectation that *than* clauses with wide-scoping universal nominal quantifiers should yield maximum-related readings parallel to those with wide-scoping universal modals is based on a particular assumption about how the *than*-clause interpretation proceeds. Nouwen & Dotlačil adopt Beck's (2010) proposal that the sets of intervals yielded by the LFs in (4) and (5) are subject to a pair of operators that (i) choose the maximally informative (i.e. smallest) such interval and then (ii) select the greatest degree from that interval. With a wide-scoping universal modal as in (4), this yields the maximum permissible degree of length, i.e. the paper's length in the accessible world where it is longest. With a universal nominal quantifier as in (6), it would yield the maximum height of any girl, i.e. the height of the tallest girl. If this is the contribution of the *than* clause in each case, then it is indeed a mystery why examples with wide-scoping nominal quantifiers, like (6), lack maximum-related readings.

But Beck's selection theory is not the only way to proceed with the interpretation of the *than* clause. Heim (2006) proposes that what we see in (4) and (5) are the complete semantic values for these *than* clauses. In other words, for Heim, the *than* clause denotes a generalized quantifier over degrees, and the *than* clause itself raises to take scope. As long as the *than* clause takes scope above the matrix differential, we generate a pair-list reading for an example like (6), not a maximum-related reading. Expectations about whether a *than* clause with a wide-scoping universal nominal quantifier should generate a maximum-related reading are thus tied to the choice of implementation. And as we will see below in section 3, there are independent reasons to favor an approach that has the *than* clause denote a degree quantifier rather than a degree term. (For discussion and sample derivations within Heim's approach, see Heim 2006, Beck 2010, and Fleisher 2016, 2018.)

A second reason to question Nouwen & Dotlačil's analysis is that the high scope position they propose for nominal quantifiers in *than* clauses is structurally analogous to what has been proposed for quantifiers in pair-list readings of questions (Chierchia 1993, Dayal 1996, 2016, Szabolcsi 1997). Rather than propose novel structure in the upper periphery of the *than* clause, we might achieve a more general analysis by pursuing connections between *than* clauses and questions. In section 3, I review a broad array of arguments from Fleisher (2018) that support treating *than* clauses as embedded questions. Then in section 4, I sketch an analysis of nominal scope-taking in *than* clauses that treats it on a par with pair-list readings more generally.

Both of these considerations–the non-trivial connection between the maximum-related reading with nominal quantifiers and the style of implementation, and the strong parallel we find with questions, including non-degree questions–would appear to weaken the case for Nouwen & Dotlačil's proposed revision of the Heim–Kennedy Constraint. On the first score, it is possible to craft an analysis where a nominal quantifier takes scope immediately beneath a *wh* interval operator without erroneously generating a maximum-related reading. On the second, pair-list readings are found even in the absence of a degree operator whose scope the nominal quantifier putatively must escape.[2]

[2]Nouwen & Dotlačil (2017: 16) note a further worry about their proposal, namely the fact that it "relies on the modelling of anaphoric dependencies in dynamic semantic frameworks, which is odd given that we are dealing with an essentially

3 Parallels between *than* Clauses and Embedded Questions

Than clauses and embedded questions show some remarkable syntactic and semantic similarities. Diagnostics from *wh*-movement, scope, binding, and quantificational variability suggest a close connection between the two constructions (Lerner & Pinkal 1991, Moltmann 1992, Moltmann & Szabolcsi 1994, Zhang & Ling 2017, Fleisher 2018). Moreover, by attending to the ways in which *than* clauses resemble embedded questions, we gain new arguments for treating *than* clauses themselves as scope takers rather than as degree terms. In this section I sketch these parallels and set the stage for the analysis of pair-list readings in the next section.

It has long been recognized that comparative *than* clauses contain a *wh* or A′ dependency involving the degree argument position (Bresnan 1973, Chomsky 1977), as evidenced by this position's variable sensitivity to different classes of islands for extraction. In this, *than* clauses mirror *wh*-questions. Examples are shown in (7).

(7) a. John is taller than Mary says he is __.
b. ??John is taller than Mary wonders whether he is __.
c. *John is taller than the rumor that he is __ caused a scandal.

Beyond this syntactic similarity, *than* clauses and questions behave alike with respect to a number of semantic diagnostics. The matrix-scope-like pair-list reading that we find with nominal quantifiers in *than* clauses is also found with embedded questions, as shown in (8) (Lerner & Pinkal 1991, Moltmann 1992).[3] An embedded-clause quantifier can make a matrix subject quantificationally dependent on it in both *than* clauses and embedded questions, as in (9) (Moltmann & Szabolcsi 1994).[4] Binding data point toward a syntactic scope-taking account of this inversion, as in (10), where QR of the embedded clause would move the bound pronoun outside the scope of its antecedent (Szabolcsi 1997). And *than* clauses mirror embedded questions in supporting quantificational variability effects in the presence of an appropriate quantificational adverbial, as in (11) (Fleisher 2018).

(8) a. John is taller than every girl is.
b. John knows how tall every girl is.

(9) a. Some boy is exactly six inches taller than every girl is. OK: *every* > *some*
b. Some boy knows how tall every girl is. OK: *every* > *some*

(10) a. Some boy$_1$ is exactly six inches taller than every girl says he$_1$ is. * *every* > *some*
b. Some boy$_1$ knows how tall every girl says he$_1$ is. * *every* > *some*

(11) a. For the most part, John is less than a foot taller than every girl is.
'John is less than a foot taller than most girls'
b. For the most part, John knows how tall every girl is.
'John knows how tall most girls are'

non-anaphoric phenomenon here."

[3] I confine my attention here to matrix predicates that select both interrogative and non-interrogative complements ("responsive" embedders, in the terminology of Lahiri 2002; predicates that select "extensional" complements, in the terminology of Groenendijk & Stokhof 1984).

[4] The inclusion of a non-upward-entailing differential is crucial for differentiating the inverse-scope reading from the surface-scope reading. Larson (1988), Nouwen & Dotlačil (2017), and Zhang (this volume) claim, on the basis of examples like *Some boy is taller than every girl is*, that such inversion is impossible. But here the inverse-scope reading ('for every girl *g*, some boy is taller than *g* is') entails the surface-scope reading ('some boy is taller than the tallest girl'), and vice versa.

Examples like (9a) are of particular interest, as they help us decide among theories of *than*-clause composition. The inverse-scope reading of this sentence is true iff for every girl *g*, there is some boy who is exactly six inches taller than *g* is. Unlike in other well-known cases with a non-monotone matrix differential phrase, here there is no inference that the girls are all equal in height. Theories that derive the same-height inference via the internal composition of the *than* clause (Alrenga & Kennedy 2014) or via the interaction between the *than* clause and the non-monotone differential (Beck 2010, Zhang & Ling 2015) thus have difficulty accounting for such examples.

As a general matter, scope inversion presents difficulties for theories in which the *than* clause denotes a degree or interval that saturates an argument position in the matrix clause ("encapsulation" theories, in the terminology of Fleisher 2016; for a novel analysis of non-monotonic quantifiers in *than*-clauses that falls within this class, see Zhang, this volume). In order to evaluate the truth of (9a) on the inverse-scope reading, we need to know all of the girls' heights. This is information that encapsulation theories tend to discard, retaining only the height of the tallest girl (or the heights of the tallest and shortest girls). A natural way to get the girls' heights is to quantify over the girls. This is precisely what "entanglement" theories do, typically by having the *than* clause take scope. In such a configuration, the *than*-clause-internal nominal quantifier attains widest scope when the full clause is composed (for details and discussion, see Fleisher 2016).

The empirical considerations stemming from examples like (9a) thus lead us to prefer the entanglement approach to comparatives (Fleisher 2018). This yields yet another parallel with embedded questions, where pair-list readings and related phenomena have led many to treat embedded questions as scope takers (Chierchia 1993, Szabolcsi 1997, Lahiri 2002). Alongside the syntactic and semantic parallels adduced above, this helps point us in the right direction for our analysis of *than*-clause-internal quantifiers.

4 Pair-List Readings in Questions and Comparatives

The wide-scope readings that we find with nominal quantifiers in *than* clauses are remarkably similar to the pair-list readings we find with quantifiers in questions. In this section I sketch an analysis of *than* clauses that treats them as embedded degree questions. I identify the high scope position that Nouwen & Dotlačil (2017) propose for *than*-clause-internal quantifiers with the high scope position that Chierchia (1993) proposes for quantifiers in pair-list readings. The result is an analysis of quantification in *than* clauses that capitalizes on our understanding of quantification in questions, and that pushes us toward a unification of these two domains.

I begin by laying out some proposals from Fleisher (2018) about the internal and external syntax of the *than* clause. I propose that the *than* clause (or, more precisely, the clausal complement of *than*) has the structure and interpretation of a degree question. I follow Chierchia (1993) and Szabolcsi (1997) in proposing that this question constituent is in fact a lifted question, i.e. a generalized quantifier over questions. As a result, it must raise to take scope. Its trace serves as the argument of an answerhood operator, AnsDeg, introduced by *than*; AnsDeg is defined in (12) and exemplified in (13).[5] This operator returns the degree found in the maximally informative answer to the question. A sample derivation is shown in (14).

[5] AnsDeg is identical to the operator I call ANS_d in Fleisher (2018). I have changed its name here in order to avoid any terminological confusion with the answerhood operator of Dayal (1996), which is often called Ans_D or similar. Dayal's Ans_D returns a proposition; AnsDeg returns a degree.

(12) $\textsc{AnsDeg}_w(Q) = \iota d[\textsc{abst}(Q)(d) = \textsc{maxinf}_w(Q)]$, where:

a. $\textsc{abst}(Q)$ is the intension of Q's abstract (in the sense of George 2011)[6]

b. $\textsc{maxinf}_w(Q)$ is the strongest true answer to Q in w (cf. Beck & Rullmann 1999)

(13) a. $\textsc{abst}(\text{how tall is John?})(d) = {\wedge}\text{tall}(\text{John}, d)$

b. $\textsc{maxinf}_w(\text{how tall is John?})$
$= \textsc{maxinf}_w(\lambda p.\exists d : p = {\wedge}\text{tall}(\text{John}, d))$
$= {\wedge}\text{tall}(\text{John}, d_{J,w})$ (where $d_{J,w}$ = John's max height in w)

c. $\textsc{AnsDeg}_w(\text{how tall is John?})$
$= \iota d[\textsc{abst}(\text{how tall is John?})(d) = \textsc{maxinf}_w(\text{how tall is John?})]$
$= \iota d[{\wedge}\text{tall}(\text{John}, d) = {\wedge}\text{tall}(\text{John}, d_{J,w})]$
$= d_{J,w}$

(14) Mary is taller than John is.

a. LF: [*wh* λ1 John is t_1-tall] λ2 [Mary is taller than t_2]

b. Semantic value: $\lambda\mathcal{Q}.\mathcal{Q}(\text{how tall is John?})$ $(\lambda Q.\text{Mary is taller}_w \text{ than } \textsc{AnsDeg}_w(Q))$
$= 1$ iff Mary is taller_w than $\textsc{AnsDeg}_w(\text{how tall is John?})$
$= 1$ iff Mary is taller_w than $d_{J,w}$

In his analysis of questions, Chierchia (1993) proposes that pair-list readings arise when a subject is quantified into a lifted question, as sketched in (15).[7] Chierchia implements this via a syntactic absorption operation that moves the quantifier above the interrogative complementizer. As Dayal (2016: 112ff.) emphasizes, the key semantic requirement is that the quantifier be interpreted outside the question nucleus, i.e. above the point at which the essential propositional variable is introduced (C, on most accounts). If *than* clauses share the basic structure and interpretation of questions, then we can analyze *than*-clause-internal quantifiers along these lines.

(15) $[\![\text{than every girl is tall}]\!] = [\![\text{how tall is every girl?}]\!] = \lambda\mathcal{Q}.\forall x \in \text{girl} : \mathcal{Q}(\text{how tall is } x?)$

When this lifted-question-style *than* clause raises and takes scope, the embedded quantifier ends up with widest scope, yielding a pair-list reading:

(16) John is taller than every girl is.

a. LF: [*wh* λ1 every girl is t_1-tall] λ2 [John is taller than t_2]

b. Semantic value: $\lambda\mathcal{Q}.\forall x \in \text{girl} : \mathcal{Q}(\text{how tall is } x?)$ $(\lambda Q.\text{John is taller}_w \text{ than } \textsc{AnsDeg}_w(Q))$

[6] A question's abstract is its syntactic and semantic skeleton, the structure that serves as the argument of an interrogative operator. As George (2011: 23) puts it, following Groenendijk & Stokhof (1984), "it is what is structurally common to a '*wh*'-question and the analogous relative clause…. [T]he intension of an abstract will be the property (or relation) that the '*wh*'-question is a question about." The intension of the abstract of the question *how tall is John* is the function $\lambda w\lambda d.\text{tall}_w(\text{John}, d)$. Strictly speaking, then, in my notation above, $\textsc{abst}(Q)(d)$ is a shorthand for ${\wedge}\textsc{abst}(Q)(w)(d)$, the result of supplying the intension of Q's abstract with world and degree arguments and taking the intension of the result.

[7] Chierchia's actual proposal involves existential quantification over minimal witness sets of the quantifier, not quantification by the quantifier itself. This is to account for the unavailability of pair-list readings with downward-entailing quantifiers, a restriction that we find in *than* clauses as well; for further discussion, see Szabolcsi (1997), Lahiri (2002), Beck (2010), Aloni & Roelofsen (2014), and Dayal (2016). For perspicacity's sake, I will use the simpler notation involving direct quantification by the quantifier, with the understanding that this should be taken as a shorthand for a treatment in terms of witness sets. Note in this connection that it is not clear how to prevent downward-entailing quantifiers from taking exceptionally high *than*-clause-internal scope in Nouwen & Dotlačil's (2017) theory.

= 1 iff $\forall x \in$ girl : John is taller$_w$ than AnsDeg$_w$(how tall is x?)
= 1 iff $\forall x \in$ girl : John is taller$_w$ than $d_{x,w}$

A nominal quantifier thus achieves wide scope inside a *than* clause just as it does in an embedded question; when the embedded constituent (*than* clause or question) itself takes scope, we get a pair-list reading. By treating the *than* clause as an embedded degree question, we avail ourselves of the scope-taking mechanism(s) that have been proposed for quantifiers in questions.

One might object that in assimilating the analysis of *than*-clause-internal quantifiers to that of question-internal quantifiers, we are trading one set of mysteries for another. It is unclear what permits quantifiers to move to such an unusually high position in questions; the questions literature has produced no consensus on the matter. Analyses of quantifiers in questions differ both in their underlying architecture (e.g. whether they treat pair-list readings as a type of functional reading) and in their empirical coverage (e.g. whether they account for certain domain exhaustivity inferences); for a recent overview and discussion, see Dayal (2016: ch. 4). Moreover, it is unclear whether the behavior of quantifiers in *than* clauses can help us choose among the analyses that have been proposed in the questions literature.

That said, the syntactic and semantic parallels between *than* clauses and embedded questions are, I suggest, too numerous and thoroughgoing to ignore. While there are many analyses of quantifiers in questions, they largely agree on an exceptionally high scope position for quantifiers in pair-list readings, much as Nouwen & Dotlačil suggest for *than* clauses. Rather than treat quantifiers' behavior in *than* clauses as a quirk stemming from a reformulated Heim–Kennedy Constraint, we can appeal to what has been observed and proposed for quantifiers in embedded *wh*-clauses of all kinds, including those without degree abstraction. If the mysteries of *than*-clause-internal scope-taking are the same as those of question-internal scope-taking, then our stock of mysteries is reduced.

5 Functional Readings

If *than* clauses are to be analyzed as embedded questions, then all else being equal we should expect quantifiers in *than* clauses to exhibit the same range of readings as we find with quantifiers in questions. In this section I examine a case where this parallel fails: functional readings. Question-internal quantifiers, including those in degree questions, give rise to functional readings, but *than*-clause-internal quantifiers do not. Here I suggest that this is due to an independent factor in *than* clauses: the AnsDeg operator, which needs to return a degree. Functional readings of degree questions involve abstraction over functions rather than over degrees, with the result that AnsDeg cannot return a degree as required. The lack of functional readings in *than* clauses thus does not undermine the proposal to treat *than* clauses as embedded questions.

Functional readings of questions are those where the answer can be stated in the form of an abstract function (as opposed to the complete graph of a function, as on a pair-list reading). Examples with non-degree and degree questions are shown in (17).

(17) a. Q: Which book did every student$_1$ read?
A: The one her$_1$ advisor recommended.
b. Q: How tall is every girl$_1$?
A: Taller than her$_1$ mother.

One salient difference between functional readings and pair-list readings is that functional readings are available even with downward-entailing quantifiers, as shown in (18). (I turn to embedded questions here, as matrix *wh*-questions support a narrower range of quantifiers; for discussion, see Szabolcsi 1997.)

(18) a. John knows which book no student$_1$ read: the one her$_1$ advisor recommended.
b. John knows how tall no girl$_1$ is: as tall as her$_1$ father.

Where ordinary individual questions are typically analyzed as involving existential quantification over individuals, functional readings involve quantification over Skolem functions, i.e. functions from individuals to individuals (Engdahl 1986, Chierchia 1993). In the (a) examples above, the answer to the question (or the specification of John's knowledge, in the embedded question case) includes a type $\langle e,e\rangle$ function: λx.the book x's advisor recommended.

In the (b) examples, by contrast, the answers/specifications involve functions from individuals to degree quantifiers, type $\langle e,\langle dt,t\rangle\rangle$, as shown in (19).

(19) a. *taller than her mother* $\rightsquigarrow \lambda x\lambda D.max(D) > max(\lambda d.\text{tall}(x\text{'s mother}, d))$
b. *as tall as her father* $\rightsquigarrow \lambda x\lambda D.max(D) \geq max(\lambda d.\text{tall}(x\text{'s father}, d))$

The (non-lifted) semantic values of an ordinary degree question and a functional degree question are shown in (20a) and (20b), respectively. When we supply the function from (19b) as the value for f in an answer to (20b), we get an appropriate answer meaning–viz. that no girl is as tall as her father is–as shown in (21).

(20) a. $[\![\text{how tall John is}]\!] = \lambda p.\exists d : p = {\wedge}\text{tall}(\text{John}, d)$
b. $[\![\text{how tall no girl is}]\!] = \lambda p.\exists f : p = {\wedge}\text{no girl}(\lambda x.f(x)(\lambda d.\text{tall}(x, d)))$

(21) ${\wedge}\text{no girl}(\lambda x.[\![(19b)]\!](x)(\lambda d.\text{tall}(x, d)))$
$= {\wedge}\text{no girl}(\lambda x.max(\lambda d.\text{tall}(x, d)) \geq max(\lambda d.\text{tall}(x\text{'s father}, d)))$

When we turn to *than* clauses, we find that the functional readings we see in degree questions are missing. While the content of John's knowledge in (22a) can be, for example, the function named by *exactly as tall as her mother*, there is no reading of (22b) where it comes out true just in case John's height relative to his mother exceeds every girl's height relative to hers (e.g. where every girl is exactly as tall as her mother and John is taller than his mother).

(22) a. John knows how tall every girl is.
b. John is taller than every girl is.

How can we account for this disparity? The question is particularly urgent for an analysis that treats *than* clauses as embedded degree questions, as I have proposed above. Why do quantifiers in degree questions support a reading that those in *than* clauses do not?

I suggest that the answer lies in the way that a *than* clause must be integrated into the rest of the comparative sentence. In the semantics sketched in the previous section, the *than* clause–or, more precisely, its question-type trace–must be mapped onto a degree that can serve as the standard of comparison in the main-clause degree relation. This mapping is effected by the AnsDeg operator, which takes a degree question and extracts the degree in its maximally informative true answer.

In a functional reading, the question involves existential quantification not over degrees, but

over type $\langle e,\langle dt,t\rangle\rangle$ functions, as shown in (20). The maximally informative true answer to (20b) is the one whose value for f yields the strongest proposition; in other words, it is the proposition ^no girl($\lambda x.f(x)(\lambda d.\text{tall}(x,d))$) that entails ^no girl($\lambda x.f'(x)(\lambda d.\text{tall}(x,d))$), for all f'. This is not a denotation from which AnsDeg can extract a degree. The reason is that a functional question of this sort is not a question about degrees; it is a question about relations between individuals and degree quantifiers. Unlike with ordinary degree questions, the answers to a functional degree question do not vary with respect to the value of the degree argument of the core scalar predicate, and the maximally informative true answer is not one that can be expressed via a simple scalar value (e.g. *six feet*). The mechanics of the AnsDeg operator are meant to reflect this deeper semantic property: AnsDeg cannot return a degree from a functional degree question because such questions are about something other than degrees.[8] If the work of a *than* clause is to take a question-like structure and deliver a degree that can be used in a matrix degree relation, then functional degree questions will be excluded (alongside all non-degree questions).[9]

The fact that *than* clauses fail to support functional readings while ordinary embedded degree questions allow them thus should not be taken as a strike against the theory proposed here. The absence of functional readings in *than* clauses is due to an independent fact about their external syntax and semantics, one that appears to have no bearing on the deep and abiding internal parallels between *than* clauses and degree questions.

6 Summary and Outlook

The question of how nominal quantifiers interact with degree operators is a major challenge and mystery, as the abundant literature of the last twenty years attests. Here I have suggested that insights from the questions literature may shed new light on this mystery. Comparative *than* clauses share a large number of syntactic and semantic properties with degree questions, including, crucially, properties relating to the behavior of nominal quantifiers within them.

Questions with quantifiers–including degree questions–support at least three types of readings: pair-list readings, functional readings, and what Nouwen & Dotlačil (2017) call single-point readings. Answers of these three varieties are shown in (23). The three readings correspond to the three different lifted-question meanings shown in (24); note that lifting is truth-conditionally vacuous in the functional and single-point cases (Chierchia 1993).[10]

(23) John knows how tall every girl$_1$ is:

[8] Note in this connection that the abstract of a functional degree question will take a type $\langle e,\langle dt,t\rangle\rangle$ argument where an ordinary degree question abstract takes a type d argument. We thus cannot supply a degree argument to the intension of a functional degree question's abstract, as would be required according to the definition of AnsDeg.

[9] I hasten to add that this characterization should not be misread as an endorsement of an encapsulation approach to *than* clauses (Fleisher 2016). In cases where the *than* clause contains a quantificational subject, the Chierchia/Szabolcsi-style lifted-question approach adopted here ensures that the structure that AnsDeg operates on is one that excludes the quantifier; indeed, AnsDeg falls within the scope of the quantifier, as is characteristic of entanglement theories. See (16).

[10] Note that the expression in (24c) correctly captures the single-point reading only if we take the gradable predicate to have an 'exactly' semantics; elsewhere, I have been assuming that such predicates have an 'at least' semantics. Alternatively, we could stipulate an 'at least' denotation like the following: $\lambda\mathcal{Q}.\mathcal{Q}(\lambda p.\exists d : p = {}^\wedge\forall x \in \text{girl} : max(\lambda d'.\text{tall}(x,d')) = d)$. It remains mysterious why, when a quantificational subject scopes low in a degree question or *than* clause, we are bound to find a single-point reading and never a minimum-related reading, which we would get on an 'at least' semantics for (24c). I leave a fuller investigation of the single-point reading to future work.

a. Anne is 5-foot-6, Becca is 5-foot-8, … PAIR-LIST
b. as tall as her$_1$ mother. FUNCTIONAL
c. 5-foot-6. SINGLE-POINT

(24) a. $\lambda\mathcal{Q}.\forall x \in \text{girl} : \mathcal{Q}(\lambda p.\exists d : p = {}^\wedge\text{tall}(x, d))$ PAIR-LIST
b. $\lambda\mathcal{Q}.\mathcal{Q}(\lambda p.\exists f : p = {}^\wedge\forall x \in \text{girl} : f(x)(\lambda d.\text{tall}(x, d)))$ FUNCTIONAL
c. $\lambda\mathcal{Q}.\mathcal{Q}(\lambda p.\exists d : p = {}^\wedge\forall x \in \text{girl} : \text{tall}(x, d))$ SINGLE-POINT

The single-point reading involves a presupposition that all of the girls are equal in height (Nouwen & Dotlačil 2017); an interlocutor who understood (23) on its single-point reading might reasonably object to this presupposition in an appropriate context. Importantly, *than* clauses support this reading, as well, despite its near-total absence from the discussion in the literature. For example, in response to a polar question like *Is John taller than every girl is?*, one might reasonably object that not all the girls are equally tall.

The parallels between *than* clauses and degree questions are thus quite extensive. Wide-scope readings for nominal quantifiers in *than* clauses appear to be entirely parallel to pair-list readings of quantifiers in embedded questions, as borne out by diagnostics involving scope inversion, quantificational variability effects, and unavailability with downward-entailing quantifiers. Functional readings are absent from *than* clauses due to an independent requirement of the matrix degree relation (implemented via the AnsDeg operator in the analysis here), not because of any internal structural disparity between *than* clauses and degree questions. And both constructions support single-point readings.

This leads to a set of theoretical takeaways quite different from what we started with. In particular, the analysis of *than* clauses as degree questions suggests a very different outlook on the Heim–Kennedy Constraint. As seen in (24), both functional readings and single-point readings involve a nominal quantifier taking scope above a degree variable but below the operator that binds it. These are configurations that the Heim–Kennedy Constraint rules out, apparently erroneously, on either its typical formulation or the reformulation proposed by Nouwen & Dotlačil (2017).[11]

The pair-list reading that we find with nominal quantifiers in *than* clauses appears, then, to result from how the quantifier interacts with the interrogative complementizer–however incompletely understood these interactions may remain–not from any (even more poorly understood) constraint on scopal interactions between nominal quantifiers and degree expressions. I hope that the present approach may afford new insights on the interactions between quantifiers and degrees, and that it may help us achieve an explanation or elimination of the Heim–Kennedy Constraint.

[11] In the case of the functional reading in (24b), the variable in question is f, which is strictly speaking not a degree variable but a variable of type $\langle e,\langle dt,t\rangle\rangle$, mapping individuals to degree quantifiers. It is therefore not entirely clear whether we should expect the Heim–Kennedy Constraint to bar the nominal quantifier from scoping between it and the existential operator that binds it. The syntactic element whose denotation is f (or $f(x)$, if we adopt a Chierchia-style double-indexing approach) originates in the degree argument position within the *than* clause and takes scope via QR. Its scope relative to the nominal quantifier appears to obey the Heim–Kennedy Constraint; there is no available variant of (24b) with a reading where the degree quantifier $f(x)$ outscopes *every girl*. On the present analysis, however, we need not appeal to the Heim–Kennedy Constraint to explain this; $f(x)$ must scope below the nominal quantifier because it needs the nominal quantifier to bind its internal argument, x.

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