# What’s in a quantifier?

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**Abstract**

In this article, I discuss several inquiries into the meaning of expressions of quantity. It is to some extent received wisdom that quantifiers are not expressions that stand proxy for amounts, quantities, frequencies, etc. In cognitive psychology, a common observation is that quantifiers express perspectives on quantity. I will argue that while this result bears some relation to notions known from formal semantics, the dominant theoretical framework, generalised quantifier theory, nevertheless falls short of providing a unifying approach to logical, linguistic and psychological aspects of quantity expressions. The upshot is that the many diverse ways in which quantity information may be worded should be reflected in a variety of analyses. In other words, quantifiers need to be approached on a case by case basis.

## 1 Introduction

The democracy of the internet can appear to give rise to some amazing insights. Jyte.com is a web-site where one can submit statements which are evaluated by visitors of the site who vote either in favour or against. After someone submitted the claim in (1), a striking discussion about quantifiers emerged.

(1) I tend to take ‘a couple’ to mean exactly two

In Dutch, my native language, ‘een paar’ (literally, a pair) is, at first sight, used in much the same way as ‘a couple’ is in English. However, it is perfectly fine for me to say (2) in a situation where I got three or four books out of the library.

(2) Ik heb een paar boeken uit de bibliotheek gehaald.
I have a pair books from the library taken.
‘I got a few books from the library’

My personal experience with (British) English is that ‘a couple’ tends to be somewhat more faithful to the lexical meaning of ‘couple’: ‘to invite a couple of friends’ means to invite two friends, no more. The democracy of jyte.com, however, proved my intuitions partially wrong: eighteen voters agreed with (1), sixteen disagreed. Several reasons were given for disagreeing, ranging from plain intuition to arguing that ‘a couple’ can’t mean ‘two’ because ‘two’ already does.

The statement in (1), however, sparked the interest of the jyte community into quantifiers, resulting in a number of statements designed to try and tackle the question of how quantifiers compare to one another. For instance, there was widespread agreement (34 in favour - 0 against) that ‘a pair’ means exactly two, and that ‘a handful’ is more than ‘a couple’ (27-0). Here is an overview of the resulting votes with respect to some other quantifiers.

(3)

| | | | |
|---|---|---|---|
| ‘lots’ | > | ‘many’ | 16-7 |
| ‘many’ | > | ‘several’ | 23-1 |
| ‘several’ | > | ‘a few’ | 24-1 |
| ‘a few’ | > | ‘a handful’ | 2-21 |
| ‘oodles’ | > | ‘lots’ | 24-2 |

Such comparisons reflect a strange frustration language users have about the expression of quantity, namely that there appears to be no *neat* order of things. We never acquire any specific knowledge of how many ‘many’ really is, nor what the difference (in quantity) is between ‘many’ and ‘lots’.

This frustration has also been a scientific one. As I will discuss in section 2, the jyte discussion is reminiscent of a certain line of psychological investigation that has proven popular in the past decades. From a more theoretic perspective, the meaning of quantifiers has been on the scientific agenda since Aristotle’s *de interpretatione*. However, the bulk of the post-Aristotelean discussion will do little to settle issues such as those in (1) and (3). This is because if anything is clear about quantifiers, it is that they are not simply words that stand proxy for amounts, quantities, numbers, frequencies, proportions, etc. That is, as we will see, you do not learn what a quantifier means by comparing it to other quantifiers or to a (precise) quantity. I will illustrate this from the point of view of theoretical semantics in section 4, after approaching it from a more psychological perspective in section 3.

In a nutshell, the problem is that quantifiers form an enormously varied group of linguistic expressions. Some of these are vague, some are imprecise and yet others denote exact quantities. Comparing quantifiers of all kinds with each other in order to find out something about their meaning would miss the point that there are significant differences in how precise, imprecise and vague expressions are used. Many quantifiers moreover encode an evaluation of the quantity they communicate. That is, they approach quantity information from a particular perspective. Such intricacies complicate matters even further.

If, however, comparisons like those of (3) do not help in discovering the meaning of quantifiers, then what will? Below, I will be on the look out for a general model of quantifier meaning. In particular, I will discuss to what extend a reconciliation between logical, linguistic and psychological approaches is possible and desirable. As we will see, there is a gap between empirically motivated psychological models of quantifier meaning and the models provided by formal semantic theory. This gap will turn out to be difficult to bridge. The modest objective of this paper is to at least pinpoint some of the underlying problems. One of the most serious problems for reaching a satisfying model of quantifier meaning, I will argue, is that there may not really be a way of making theoretical sense of the notion of a *quantifier* itself.

# 2 Words and Numbers

## 2.1 Ordering Quantity Expressions

There exists a long line of (largely psychological) literature which questions how people use quantity expressions and how, in language use, such expressions line up (Simpson 1944 is the earliest attempt I know). The *ordering* of expressions is often thought to be important for the purpose of understanding the communication of quantitative information, especially in domains where more precise information is valuable, such as is the case for conveying medical information. O'Brien 1989 asked general practitioners to imagine a situation where they had to communicate the likelihood of there occurring a certain side-effect with a drug. They then had to map twenty-three frequency quantifiers onto a percentage scale. In similar experiments also geared at medical practice, (Renooij and Witteman 1999) set out to find "an acceptable representation of a probability scale that [contains] mutually exchangeable verbal and numerical expression" (p. 30). In other words, the goal of such work is to eliminate the gap between words and numbers, by experimentally finding out how they correspond to one another.

In studies of questionnaire design, quantifiers have received similar attention. Bradburn and Miles 1979 ask how to interpret responses to survey questions made using vague quantifiers. They report on an experiment where subjects fill in a survey where the response categories form a scale of vague (frequency) quantifiers. They are then subsequently asked what their responses 'meant'. That is, somebody answering 'often' to a certain questions had to specify 'exactly how many times a day' this corresponded to (p. 95). (See Pace and Friedlander 1982 for a similar study). Pracejus et al. 2004 investigate the interpretation of cause-related marketing slogans that come with products ('a portion of the proceeds goes to charity'). One of their studies involved subjects estimating amounts donated to charity for a purchased item given the product's price and a particular slogan.

A common result of such studies into practical applications of quantifier meaning is considerable between-subject variation with respect to how a certain quantifier relates to some value. In many cases, this finding seems to be a major cause of concern for the authors. Pace and Friedlander, for instance, remark that "if there are substantial differences in the way people interpret the labels [i.e. the vague quantifier response categories (RN)], then, unlike standardized objective test data, interinstitutional comparisons are of questionable value" (Pace and Friedlander 1982, p. 267). Such worries lead researchers to investigate what contextual parameters are responsible for differences in how vague labels are estimated to correspond to numerical information. Schaeffer 1991 considers social factors that might play a role, concluding that "there are significant differences by race, education, and age in the meaning of phrases conveying relative frequency" (Schaeffer 1991, p. 395)

From such lines of research there seems to spring a general consensus that quantifier-value mappings are hopelessly subject-specific and hardly useful, due to the enormous overlap between different quantifiers. Quite a few researchers saw this as an incentive to investigate the source of the mapping problem, resulting in an ongoing range of mapping experiments, witness some of the more recent papers cited above. One result of O'Brien's 1989 study of doctor-patient risk communication was that for some expressions there is huge variance in how they map to a scale. Furthermore, he observed that "the context in which a given expression of probability is used may affect its meaning" (p. 98). Nevertheless, O'Brien took the fact that some expressions showed a relatively low amount of invariance between subjects to mean that the "results are encouraging and suggest that phrases denoting likelihood might be systematically codified to enhance communication between doctor and patient" (p. 98). This was wishful thinking, rather than an informed estimation of future progress and I contest that in the 30 years after O'Brien's study we are any nearer to such a systematic codification. In fact, the style of comparison of quantifiers in such studies entails a distorted understanding of what quantifiers do. In the next section, I provide a detailed discussion of a general problem with the above view. In the remainder of the current section, I will briefly reflect on the topic of context-dependence and argue that it is an oversimplification to believe that the problem with the above experiments is simply one that can be solved by fixing the context.

## 2.2 Context Dependence and Non-Extensionality

From linguistic semantic theories of quantification it is well-known that some natural language quantifiers are severely context dependent. Compare (4-a) to (4-b).

(4) a. Many students came to my party.
    b. Some students came to my party.

Now imagine two different situations. In both, out of the eighty I invited, forty-five students came to my party. In the first situation, I sent invitations indicating that there would be an entrance fee to the party of €60 and that people had to bring their own drinks. In the second, the invitations mentioned free beer, free food and no entrance fee. Although in both situations, the number of students coming to my party is forty-five, (4-a) is much more likely to be true in the first situation, then in the last. We expect few students to come to expensive parties and many to come to parties with free food and beer. So, a forty-five out of eighty score counts as 'many' w.r.t. the first situation, but probably not w.r.t. the second. This contrasts with (4-b), which seems true irrespective of the situation. In other words, 'many', but not 'some' is context-dependent.

Context-dependence also surfaces when we compare different sentences with the same quantifier.

(5) a. There are many ants in my garden.
    b. There are many typos in this article.

The average garden has millions of ants, while the average manuscript probably has around twenty typos. So, when someone's garden counts one hundred ants, this person is unlikely to utter (5-a). However, a manuscript with one hundred typos is likely to be described as in (5-b). This is context-dependence, again. 'Many', when talking about ants differs from 'many' when talking about typos.

But things are even more complicated. Keenan and Stavi 1986 and Westerståhl 1984 show that contrasts like that in (5) surface even when 'many' talks about the same group of individuals, in the same context. Imagine a conference of lawyers and policemen where normally 60 lawyers and 40 policemen attend. Also, on average, only 10 attendants are women. This year, there are only 20 lawyers, but a staggering 80 policemen. Strikingly, all the lawyers happen to be women and all the policemen are men. In this (bizarre) situation (6-a) is probably judged to be false, but (6-b) tends to be judged as true.

(6) a. Many lawyers attended the meeting this year.
    b. Many women attended the meeting this year.

The thing to realise is that the set of attending women *is* the set of attending lawyers. This shows that if the context and the number of relevant individuals are both fixed, 'many' still gives rise to different meanings. Counting women in the above situation leads to the same amount as counting lawyers, but because the expectancy for lawyers and women differ, 'many' is sensitive to what is counted.[1]

Keenan and Stavi and Westerståhl conclude from these observations that 'many' is *non-extensional*. This means that whether 'many' lawyers attended a meeting cannot be decided on the basis of looking at the actual set of lawyers at the meeting (in relation to the actual full set of lawyers) only. Lappin 2000 proposes to account for this intuition by assigning a semantics to 'many' that crucially depends on normative situations.

(7) Lappin 2000 (paraphrased): 'many A's B' is true if and only if for every normative situation it is the case that the actual number of A's that B exceeds the number of A's that B in the normative situation

So, if in a normal situation, 60 to 80 lawyers turn up, 'many lawyers turned up' will mean that more than eighty of them came. Likewise if in a normal situation, 20 to 30 women turn up, 'many women turned up' will mean that more than thirty women came. This difference arises from what is normal and is independent of the fact that in the actual situation the number of lawyers and women is the same.

Presumably, one could, and should, understand the notion of *normative situation* broadly, even containing notions like *expected situations*, *desired situations*, etc. For example, (8-a) and (8-b) do not necessarily depend on what the average situation looks like.

(8) a. Many people saw through my disguise. *more than I expected*
b. There are many people in this queue. *more than I want there to be*

What the above shows is that 'many' is not just a word that stands in for an amount. It has a complex non-extensional relation with an amount, which depends on what is normality, what is expected, what is desired, etc. If we are optimistic, we could say that there could be a psychological agenda to find out how many is 'many' *given a context and given the speaker's expectations and such*. However, such research would be missing the point that when a speaker uses a vague quantifier like 'many', she may do so with a rather specific purpose. In the literature on vagueness, there is an emerging consensus that vague communication is *useful* (Parikh 1994; Kyburg and Morreau 2000; Barker 2002). One way in which this is manifested is that a speaker may use a vague term, without any intention of communicating the extension of that term. This can be illustrated along the lines of Barker 2002. Take a sentence like 'Cindy is tall'. When I say this to someone who does not know Cindy, the hearer will receive the vague information that Cindy is taller than some contextual standard. But when I say this to someone who knows Cindy and moreover who knows exactly how tall she is, the hearer will learn something about what I experience to be tall. In other words, in such cases, the information exchange is not about Cindy's height at all. To return to 'many', a sentence like 'many students came to my party' might have as its sole communicative function the message that the speaker is relieved, surprised or shocked by how many students came. In that sense, the sentence is not intended to communicate a quantity at all.

The moral of the above is that the elimination of vagueness from a term, strips this term from some of its key communicative functions. This still leaves open, however, the question of how vague quantifiers compare to each other. If 'few' and 'a few' are both vague, then what drives the differences in their usage? This is the topic of the next section.

# 3 Directivity

In one particular line of psychological research into quantity expressions, many arguments have been formed against reducing the meaning of quantity expressions to quantities. One particularly enlightening insight from that area is the idea that asking a subject to place multiple quantifiers on a scale creates a bias. Moxey and Sanford 1993 (cf. Moxey and Sanford 2000) gave a large group of subjects the task of assigning a number to a quantifier. Each subject, however, only got a single quantifier, which means that there could be no effect caused by the act of comparing one expression with another. On the basis of the results of this experiment, quantifiers like ‘few’, ‘very few’, ‘only a few’, ‘not many’ and ‘a few’ turned out to be indistinguishable.

Moxey and Sanford took their results to indicate that there is more to quantifier meaning than the indication of amounts, numbers or frequencies. In an influential research programme, they set out to show that quantifiers carry information about the *perspective* that is taken. The idea is that certain quantifiers express the same quantity, yet differ in how they focus on this quantity. For instance, it is conceivable that in a situation where three people came to my party I can express this with both (9-a) and (9-b).

(9) a. Few people came to my party.
b. A few people came to my party.

There is a difference, however. Whereas ‘few’ is negative in flavour, ‘a few’ is not. Below we turn to the question how to make such a ‘flavour’ precise, but for now it suffices to point out the intuition that (9-a) expresses a negative perspective of how many people came, whereas (9-b) is positive in nature. There seems to be a variety of ways to refer to the negative/positive distinction, such as *polarity, perspective* and *focus*. These terms are rather discipline-specific and often come with a particular view on the distinction. In order to have a more pre-theoretic terminology, I will use the term *directivity*.

Directivity also creates a contrast in (10). In terms of the number of people who came to my party, (10-a) and (10-b) say the same two things: (i) some did not come, (ii) but those who did not were few.

(10) a. Not quite all people came to my party
b. Almost all people came to my party.

Nevertheless, sentences like (10-a) are often called negative, while (10-b) is positive.[2] How can you tell? One of the most powerful diagnostics is to mark the sentence with an evaluative predicate, like ‘fortunately’ or ‘surprisingly’, as in (11).

(11) a. Surprisingly, not quite all people came to my party.
b. Surprisingly, almost all people came to my party.

These sentences say different things. In (11-a), the speaker expected everyone to come. In (11-b), however, the speaker expected not so many people to come. Such effects are quite robust, and are certainly not limited to a select group of evaluative adverbs. For instance, Anscombre and Ducrot 1976 notice that something like directivity influences how pieces of information may or may not connect in discourse. For instance, in (12), the information provided by the negative phrase ‘few motorists’ is given a specification in a parenthetical. In (12-a) this specification is made using the positive quantifier ‘almost 20%’, which somehow clashes with the negative perspective provided by ‘few’.[3] (See Jayez and Tovena 2007 for a formal semantic discussion of such examples.)

(12) a. ??Few motorists, almost 20%, know the details of the new highway code.
b. Few motorists, about 20%, know the details of the new highway code.

These particular kinds of manifestations of the notion of directivity have received considerable attention in psychology as well. Sanford et al. 2002, for instance, focus on contrasts like that in (13) and experimentally confirmed the intuitions for them.

(13) a. In the airplane crash, a few people were killed, which is a #good/bad thing.

b. In the airplane crash, few people were killed, which is a good/#bad thing.

On an intuitive level, such contrasts may be explained by the idea that a negative quantifier like 'few' in (13-a) focuses on the people that were not killed, while the positive quantifier focuses on the ones that were. This intuition is supported by a large set of experimental results on how directivity interacts with anaphora.

Quantifiers give rise to various kinds of (plural) discourse anaphora, involving reference to a variety of sets associated with the quantified sentence. In a sentence like 'most students came to my party', the (contextual) set of students is called the maximal set (or maxset). The set of students that came is called the reference set (or refset). Finally, the set of absent students is called the complement set (or compset). These three sets give rise to three kinds of pronominal anaphoric reference, labelled maxset reference, refset reference and compset reference. They are exemplified in (14).

(14) a. Most students came to my party. Some of them, however, stayed at home instead.
*them = maxset*
b. Most students came to my party. They had a wonderful time.
*they = refset*
c. Very few students came to my party. They stayed at home instead.
*they = compset*

The phenomenon in (14-c) is also termed 'complement anaphora'. From a series of experiments conducted in the eighties and nineties (see for instance, Moxey and Sanford 1987; Sanford and Moxey 1993; Paterson et al. 1998 and references therein) it became clear that this latter form of discourse anaphora is associated with quantifiers with a negative perspective. In fact, in continuation experiments where subjects were presented with stimuli like (15) (with Q some quantifier), positive quantifiers like 'most' only exceptionally lead to completions where the pronoun refers to the complement set.

(15) Q of the MPs attended the meeting. They…

Pairs like 'few' and 'a few' show strikingly different results. For instance, in Moxey and Sanford 1987, 'few' and 'very few' trigger many completions with complement anaphora, whereas 'a few' only does so in 5% of the cases. Similar effects are found in the interpretation of inclusion relations (which are, arguably, anaphoric in nature).

(16) a. Not many of the fans went to the match, including Fred.
b. A few of the fans went to the match, including Fred.

When asked on the basis of examples like these whether Fred did or did not go the match, subjects tend to say no to (16-a) and yes to (16-b) (Sanford, Williams, and Fay 2001).

In sum, we have seen a wealth of effects which show that quantifiers have a richer meaning and use than the mere indication of a quantity. Several models have been proposed for these effects, which are generally based on the recognition that negative quantifiers are somehow special. Rather than simply asserting a quantity, these quantifiers make salient a difference from expectation.[4] (See Sanford et al. 2007 for a precise and recent exposition.) Such a psychological model advocates the understanding that quantifier meaning is something which is more complex than quantity assertion. In the next section, I turn to the theoretical linguistic semantics and its approach to quantifier meaning, and, subsequently, I will ask whether in that discipline a result similar to that of psychology is possible. In other words, the question is whether the parameters of the psychological model correspond to parameters known in semantic theory.

# 4 Quantifier Semantics

So far, I have been loosely using terms like 'quantity expressions', 'quantifiers' and 'determiners'. It makes a lot of sense, however, to be quite a bit more explicit, since the quantifier literature is laden with terminological chaos. In the process of doing so, I introduce the single most influential theory on quantifier semantics. Subsequently, I will apply the state of the art in quantifier semantics to the effects of directivity discussed above. I will conclude by questioning the generality of the semantic framework.

## 4.1 Generalised Quantifier Theory

At least superficially, there is an obvious syntactic similarity between expressions such as 'some', 'every', 'many', 'most', 'no', 'more than fifty-five', 'between nine and ninety', etc. Aristotle already identified part of this class as responsible for creating the 'subjects' that together with predicates form propositions. In somewhat more modern terminology, Aristotle's characterisation translates in the understanding that these expressions form noun phrases, which in combination with verb phrases form sentences. According to the leading view on quantifiers in formal semantics, Generalised Quantifier Theory (Barwise and Cooper 1981; Keenan and Stavi 1986; van Benthem 1986), this syntactic similarity between the expressions is mirrored in semantics: they all express the same kind of semantic entity. In other words, from a semantic point of view, these words and phrases form a coherent class: they are a (special kind of) quantifier.

There are many unfortunate terminological issues in this part of semantics, all to do with the notion of a quantifier. Let us settle some of these first. Many things have been called a quantifier in many different disciplines. In linguistics, there are those who refer to the determiner(-like) elements mentioned above as quantifiers (e.g. 'every'), and others who reserve this term for determiner phrases (e.g. 'every student'). From a mathematical point of view, both are correct in a sense. A mathematical (generalised) quantifier is namely any relation between subsets of or relations on the domain of entities (Mostowski 1957; Lindstroem 1966). This gives rise to a typology of quantifiers. Unary relations between sets are called type (1) quantifiers, binary relations between sets are of type (1,1). A binary relation between sets and binary relations is of type (1,2), etc.

The application of mathematical generalised quantifiers to linguistics is one of the true success stories of formal semantics. Montague 1973 as well as Lewis 1970 provided the basis for a range of papers in the early eighties which in hindsight are collectively referred to as *generalised quantifier theory* (GQT, a.o. Barwise and Cooper 1981; van Benthem 1986; Keenan and Stavi 1986; Westerståhl 1984). The central idea is that there is a correspondence between noun phrases (or, in modern speak, determiner phrases) and type (1) quantifiers. Moreover, these type (1) quantifiers are the result of filling in one of the arguments of a type (1,1) quantifier. In other words, determiner-like elements correspond to (1,1) quantifiers. In what follows, I reserve the term natural language quantifier (or, if the context is in no need of such an elaborate qualification, simply quantifier) for this latter category.

As an illustration, consider the case of 'every'. In GQT, 'every' denotes a relation between sets, or properties. Two properties are in the 'every' relation if the one is included in the other. So, 'every raven is black' is true if the property of being a raven includes the property of being black. In set theoretic terms: the set of ravens is included in the set of black things. ‘Every raven’ is now a collection of properties (i.e. a set of sets): the set of properties that is shared by every raven, which includes things like being black, having wings, having a curved bill, being a bird, etc. Schematically:

| expression | denotation | type |
|---|---|---|
| every | The relation between properties A and B such that every individual that has A has property B | (1,1) |
| every raven | The set of properties that every raven has | (1) |

This kind of semantics for quantifiers helps us to understand what goes wrong when we try to compare expressions of quantity to numbers, proportions or amounts. Take ‘most’. A fairly accurate semantics (though see Ariel 2004) is given in (17), which says that ‘most’ expresses a majority relation.

(17) ‘Most A B’ is true if and only if there are more individuals that have both property A and B than there are individuals that have property A but not B. (In other words, more than fifty percent of the individuals that have property A, have property B as well).

According to this, ‘most’ simply gives a lower bound. As soon as more than fifty percent of the A’s have property B, then ‘most’ can be truthfully used. In other words, its semantics is very imprecise in the sense that it covers a wide range of percentages. Moreover, there is a sense in which this semantics predicts ‘most’ to be positive. As said, (17) specifies a lower bound. This means that ‘most’ is compatible with the top of the scale, but not with the bottom. The semantics in (17) predicts ‘Most A B’ to be true, if all A’s have property B, but not if none has. This accounts for (18).

(18) Most students passed the test. In fact, all/#none did.

In fact, there is a more general way of approaching directivity in generalised quantifier theory, namely by applying the formal notion of monotonicity. In general, an operation on a domain is *monotone* if applying the operation preserves a certain structure that exists within this domain. A quantifier is monotone when the quantifier preserves (or reverses) the subset relation between sets.[5] This is best explained by an example.

The set of people with hair has as one of its subsets the set of people with curls. ‘Most’ is *upward monotonic* (or *monotone increasing*) because if I know that ‘most professors have curls’ (the subset case), I automatically know that ‘most professors have hair’ (the superset case). ‘Less than half’ is *downward monotonic* (or *monotone decreasing*), for if I know that ‘less than half the professors have hair’ (the superset case) then ‘less than half the professors have curls’ (the subset case). ‘Exactly half’ is *non-monotone*: if ‘exactly half the professors have hair’, nothing may be concluded about whether or not ‘exactly half the professors have curls’, nor is there an inference the other way around.

It can now be hypothesised that negative quantifiers are those that are downward monotone. For instance, ‘a few’ is clearly upward monotone, while ‘few’ appears to be downward oriented. This is in accordance with our perception of ‘few’ as negative and ‘a few’ as positive.

(19) a. A few professors have curls. Therefore, a few professors have hair.
b. Few professors have hair. Therefore, few professors have curls.

However, there is a problem with the context-sensitivity of a vague quantifier like ‘few’. One could, for instance, question the validity of (19-b) by imagining a situation in which 95% of the professors are bald, but where the remaining 5% are all curly. Surely, such a situation makes the premisse true, but the conclusion false. However, it is possible to argue that what happens in such cases is that the criteria for ‘few’ in the first sentence are different from those in the second. So (19-b) is then no longer a test for monotonicity, since it contains two different quantifiers.

A different kind of test, one which eliminates context effects, clarifies matters for the case of ‘few’ (and other context-sensitive quantifiers). Say that Bob is a professor and that he has curly hair. If Bob now were to decide to straighten his hair, the set of curly people in the new situation would be a proper subset of the old set of curly people. Intuitively, Bob’s sole action does not influence the standard of comparison we associate with quantifiers like ‘many’, ‘few’ and ‘a few’, and so by comparing our intuitions about the ‘curly Bob’ situation (the superset case) to those about situation after Bob straightened his hair (the subset case), we can eliminate the influence context has on such quantifiers. Such a setup confirms the downward monotonicity of ‘few’. Clearly, Bob’s action will not matter to the truth of ‘few professors have curls’. Once true for the initial situation, it remains true after Bob’s makeover. The same does not apply to ‘a few’. If at first ‘a few professor have curls’, Bob’s straightening of his hair could render this sentence false, for it could be that Bob was the only curly professor. As already suspected, ‘a few’ is upward monotone.

## 4.2 Monotonicity and Directivity

It should be clear that GQT provides us with a basic yet powerful framework for defining a precise and general quantifier semantics, which comes with a set of tools for identifying properties of quantity expressions. The question is whether these tools suffice for the characterisation of various aspects of quantifier meaning. If negative quantifiers are monotone decreasing quantifiers, then it would be instructive to find an explanation of the diagnostics of negativity in terms of monotonicity.

In Nouwen 2003, I propose that the contrast in (20) can be explained by means of monotonicity. (See Kibble 1997; Hendriks and de Hoop 2001 for related, yet different, proposals.)

(20) a. Most students saw the match. #They went to a party instead. positive
b. Few students saw the match. They went to a party instead. negative

The way I argued was that complement anaphora is a marked form of reference, which involves an inference step: the inference of the existence of a (non-empty) compset. With a quantifier like ‘most’ such an inference is not possible.[6] The reason is that ‘most A B’ is true in case ‘all A B’. So, on hearing ‘most students saw the match’, a hearer does not know whether there are any students who did *not* see the match, and so the existence of a compset can not be inferred. In fact, all monotone increasing quantifiers are compatible with cases in which a universal statement is true and, so, all monotone increasing quantifiers preclude the inference necessary for complement anaphora.

Downward entailing quantifiers will often, but not always, allow for the inference to take place. For instance, if ‘few’ in (20-b) is taken to mean something like ‘less than twenty percent’, then we know that at least eighty percent of the students did not see the match. Complement anaphora is therefore licensed. There is a complication, however. Downward monotonicity is not a sufficient condition for inferring a non-empty compset. In a sentence like (21), the modified numeral is downward entailing.

(21) Less than twenty students saw the match.

Despite downward monotonicity, however, (21) fails to guarantee the non-emptiness of the compset, for this example could be true simply because the total number of students is fewer than twenty. In that case, it could be that there are no students who did not see the match: all of the fewer than twenty students saw the match. Indeed, negative modified numerals are relatively bad licensers of complement anaphora, and so the monotonicity theory of Nouwen 2003 would explain why negativity is a necessary, yet not a sufficient trigger of complement anaphora.

The inferences licensed by monotonicity may also account for the way evaluatives interact with quantifier meanings. Let us assume that evaluative adverbs like 'surprisingly', 'amazingly', 'fortunately' are sentence operators that predicate over a proposition.[7] A sentence like 'Surprisingly, a penguin is a bird' asserts that a penguin is a bird, while at the same time it conveys that (the speaker is of the opinion that) it is somehow unexpected that a penguin is a bird. Let us now look into what is expressed about expectation when such an adverb predicates over a quantified sentence. As observed above, (22-a) suggests that fewer people were expected at the party, while in the case of (22-b) more were expected.[8]

(22) a. Surprisingly, a few people came to my party.
b. Surprisingly, few people came to my party.

In Nouwen 2005, I argue that evaluative predicates like 'surprising' are monotone. That is, what is and isn't surprising is sensitive to entailments between propositions. If it surprises me to learn that Cindy came to Bill's party, then anything entailing that information should also surprise me. It cannot be that suddenly it does not surprise me that Cindy came to Bill's party late. In other words, 'surprise' is downward monotonic: if $p$ is surprising, then anything entailing $p$ is equally surprising.[9] Applying this to (22) gives an interesting result. Upward monotonic quantifiers, as are downward monotone ones, are related by entailments. 'A few people came to my party' is entailed by 'Many people came to my party', which in turn is entailed by 'All people came to my party'. Similarly, 'few people came to my party' entails that 'not all people came' and is entailed by 'no-one came'. This means that someone uttering (22-a) is committed to being equally surprised had the number of people who came been many. Reversely, someone uttering (22-b) is committed to being equally surprised had no-one come. To put it more succinctly, in (22-a) the top end of the scale is marked as surprising, while in (22-b) the bottom half is.

The above serves to illustrate that the formal properties of quantifiers, as provided by GQT, may help to explain why the negative/positive distinction manifests itself in the way it does. Does this mean that the denotational semantics of quantifiers may serve as a basis for a psychological model, where the monotonicity characteristics of a quantifier replaces the parameter of directivity? Despite clues that downward monotonicity and negativity are to some extent connected, the answer will have to be no. Monotonicity is too crude a measure to fully account for a much more complex phenomenon.[10] First of all, directivity effects arise in interaction with context. Moxey 2006, for instance, shows that when a subject expects a quantity to be much larger than that expressed by a *positive* quantifier, this quantifier is sometimes taken to license complement anaphora. In her experiment, when a quantifier like 'a small number of' followed sentences expressing the expectation of 'all', the number of complement anaphora completions increased significantly. In other words, positive quantifiers can turn negative in certain contexts. Monotonicity is clearly insensitive to such considerations.

The shortcomings of monotonicity are further illustrated by comparing two specific monotone decreasing quantifiers. In Moxey et al. 2001, it is found that the monotone increasing quantifier 'no less than 10%' gave, in a small number of cases, rise to negative perspective effects. In the same experiment, it was found that 'at most 90%', intuitively downward monotone, gave fewer negative-like responses than 'no less than 10%' did.[11] Clearly, there is a variation in the data that is left unexplained if directivity is mapped onto the three-way classification of quantifiers into upward, downward and non-monotonic operators.[12] As we will now see, the generality and coarseness of the generalised quantifier approach has further drawbacks.

## 4.3 Further Limitations of Generalised Quantifier Theory

Aside from applying formal tools like monotonicity to quantifier meaning, the ideas of generalised quantifier theory lead to a number of *big* questions, such as: Do all languages have these kinds of expressions? (see Barwise and Cooper 1981; Bach et al. 1995; Matthewson 2001) or How many quantifiers can there be? (van Benthem 1986). Another important issue is the question of what distinguishes a possible quantifier, from an impossible one (Barwise and Cooper 1981; Keenan and Stavi 1986; van Benthem 1986). Barwise and Cooper 1981, for instance, claim that lexical quantifiers are always monotone (be it upward or downward). That is, non-monotone quantifiers are always *derived*, like 'exactly twelve', 'between ten and thirty', 'more than six, but fewer than ten', 'precisely 50%'. Probably GQT's most well-known universal of this kind, however, is the thesis that all natural language quantifiers (lexical and derived ones) are *conservative*. Conservativity is a property which precludes quantifiers from taking into account information about individuals that fall outside the domain of their first argument (the so-called domain of quantification). For instance, to know whether 'every student is lazy', it is completely irrelevant to look at individuals who are not a student. Investigating every student will do. The same goes for 'most students are lazy', 'no students are lazy', etc. If all your knowledge was restricted to properties of students, then you would still be able to decide on the truth-value of any sentence in which a quantifier is combined with the noun 'student'.

There are, however, exceptions to the conservativity thesis, 'only' being the most commonly discussed one. If you have just studied all the files of all the students of Utrecht University, and you know nothing else about the university, then you will not be able to decide on whether (23) is true or false. (The small caps indicate that 'students' receives stress.)

(23) Only STUDENTS in Utrecht University are lazy.

The problem is that for (23) to be true, it is necessary that none of the non-students is lazy. So, you'd for instance need to study the professors as well in order to decide on (23).

Generalised quantifier theorists took this observation to mean that 'only' is not a quantifier. This makes sense because of some other special properties 'only' turns out to have. For instance, it is focus sensitive. If we change the stress in (23) from the noun to 'Utrecht', a totally different meaning emerges (which, for instance, entails that students in Leiden University are not lazy). Quantifiers like 'every' are not sensitive to focus in this way. Another difference is that the distribution of 'only' is much wider than that of 'every' and its kin. 'Only' combines with prepositional phrases ('only in AMERICA'), verb phrases ('he only LOOKS scary'), etc., while 'every' is confined to its determiner position. It is clear then that 'only' and 'every' are simply different kinds of things: 'only' is not a quantifier, 'every' is. This begs the question, however, whether or not there are more things that look like a quantifier, but turn out to be something else. As happens, the class of true natural language type (1,1) quantifiers is remarkably small.

Krifka 1999 was the first to point out that modified numerals are focus sensitive and that this is problematic for their treatment as type (1,1) quantifiers. For instance, with stress on the number word, a quantifier phrase like 'at least four children' can answer a 'how many'-question. With stress on the noun, this is infelicitous.

(24) [Q] #Who left? / How many children left? [A] At least FOUR children left.

(25) [Q] Who left? / #How many children left? [A] At least four CHILDREN left.

If 'at least four', as a complex, is a relation between sets of individuals, then how is it going to be sensitive to focus on 'four'? The least we should do is decompose this complex further. Geurts and Nouwen 2007 observe that the focus sensitivity of modified numerals can lead to truth-conditional differences.

(26) Cindy brought more than THREE bottles of wine. (She brought five.)

(27) Cindy brought MORE than three bottles of wine. (She brought some beers too.)

Note that (26), but not (27) entails that Cindy brought (at least) four bottles of wine. In fact, (27) entails that what Cindy brought (properly) includes three bottles of wine. This is problematic: if 'more than three' forms a quantifier, then 'three bottles of wine' is not a constituent.

If 'more than three' is not a type (1,1) quantifier, is 'more than three N' then at least a type (1) quantifier? According to Hackl 2000, it is not. One of his arguments is based on examples like (28) and (29).

(28) #Cindy separated more than one animal.

(29) Cindy separated at least two animals.

'To separate' is compatible with objects whose cardinality exceeds one: somebody can separate two animals, but not one animal. Given this, the contrast between (28) and (29) is unexpected, since both 'more than one animal', and 'at least two animals' are used for quantities of two animals or more. Instead of analysing 'more than one' as a complex quantifier, Hackl's solution is to assume that 'more than' is a proper comparative construction, with 'more' being the comparative form of counting quantifier 'many'. So, (28) is interpreted as [ -er [ Cindy separated d-many animals ] [ Cindy separated d-many animals & d=1 ] ]. The semantics of this says that the sentence is true if the maximal d such that Cindy separated d-many animals is larger than the maximal d such that Cindy separated d-many animals, where d is one. The example is unacceptable since one of the clauses in the comparison expresses that Cindy separated one animal. A similar structure for (29) is predicted to be felicitous, since in that case the comparison would contain a clause where Cindy separated two animals. Note that this solution is not available if we strive to view more than one as a type (1,1) quantifier.

The conclusion I want to draw from these issues is that it is a mistake to think that one can devise a *general* semantics for expressions of quantity. The reason this fails is that there is no coherent class of such expressions. Take modified numerals again. All modified numerals have in common that they contain a number word and some operator. It has become clear only very recently that there are very few other common characteristics shared by different kinds of modified numerals. For instance, Geurts and Nouwen 2007 argue that comparatively modified numerals ('more than $n$') express a completely different kind of relation to a number than superlatively modified numerals ('at least $n$') do. This might seem counter-intuitive when examining simple examples like 'Cindy ate more than three biscuits' or 'Cindy ate at least four biscuits' (which will seem equivalent), but a more detailed investigation uncovers sharp contrasts between the two kinds of quantifiers. The common factor in such contrasts, Geurts and Nouwen argue, is the intuition that ‘at least’ expresses a modal attitude towards a quantity, while ‘more than’ does not. This is illustrated in (30).[13] While (30-a) is a truism, (30-b) is strange (or, some might say, false), since it suggests that there is the possibility of a triangle having more than three sides.

(30) a. A triangle has more than two sides.
b. A triangle has at least three sides.

The negative counterparts of these quantifiers show similar effects: the word ‘bat’ has fewer than four letters, but surely it is an inappropriate thing to say that it has at most three letters. The important point to note is that such data show that there are many ways in which a quantifier may communicate quantity information. Arguably, such specific ways are the consequence of the fact that many different kinds of constructions allow the expression of quantity. So, comparatively modified numerals *are* comparatives and so have the properties of a comparative; superlatively modified numerals *are* superlatives and will share properties with the class of superlative constructions, etc. This is made especially clear by prepositional numerals. Corver and Zwarts 2006 argue that quantifiers like ‘over a hundred’ (as in ‘Cindy read over a hundred books last year’) is an adnominal PP. They moreover argue that prepositions in such quantifiers keep their normal spatial meaning, except that dynamic prepositions loose their motion sense. Nouwen 2008a, moreover, argues that some dynamic prepositions that lack a locative meaning have a fully directional meaning when they form a prepositional quantifier. The details of this argument are beyond the scope of the present paper, but, as an illustration, notice for instance that while ‘up to’ places an upper bound on a quantity, it nevertheless is positive (in line with its upwards direction), this in contrast with other upper bound modified numerals.

(31) Surprisingly, Cindy can be sentenced to up to six years in prison. less expected

(32) Surprisingly, Cindy can be sentenced to at most six years in prison. more expected

Putting it differently, variation in quantifier meanings is not simply due to a varied lexicon of quantifiers, but rather due to a variety of constructions that have the possibility of referring to quantities. The behaviour of the quantifier ‘up to six’ should not be sought in a *quantifier semantics*, but rather in the normal spatial meaning of the preposition.

I started this section by saying that it makes sense to try and make precise what we mean with a (natural language) quantifier. It turns out that this is not a straightforward question to answer. There are probably only few true quantifiers, in the type (1,1) sense (‘every’, ‘no’, probably ‘most’ and ‘some’).[14] Attempts to generalise over a larger group of expressions of quantity miss out on distinctive semantic features. The key observation is that there is enormous variation in *how* quantities are expressed. Linguistic tools that exist independent of quantification may be exploited for that purpose (comparison, superlativity, spatial prepositions of direction, approximatives, etc.) The result sometimes resembles a type (1,1) quantifier, but in many cases, it does not.

# 5 Conclusion

The conclusion of the previous section was a rather negative one: the GQT notion of a quantifier is not really very suitable if we want to learn more about the semantics of expressions of quantity. If we want to appreciate the subtle differences with which quantifiers communicate quantities, a focus on how they differ is to be preferred over one which sets out to generalise as much as possible. While I showed that to some extent there is a relation between a notion like negativity and a formal property like downward monotonicity, such properties turn out too coarse to fit the data. So what's in a quantifier? Lots of stuff. The things we call 'quantifier' are so varied, that they deserve to be studied on a case by case situation.

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# Notes

[1]This example is from Keenan and Stavi 1986. Westerståhl 1984 shows a similar effect for when the verb phrase is varied:

(I) a. Many students in the class got the highest mark on the exam.
b. Many students in the class are right-handed.

Imagine a situation in which in some thirty-student class, ten of the students got the highest mark on the exam, but that these ten happen to be all the right-handed students. In such a situation (32-a) tends to be thought of as true (one would expect fewer students to have the highest mark), while (32-b) tends to be judged false (normally, there would be more right-handed students).

[2]An anonymous reviewer justly complains that the labels 'positive' and 'negative' are always interpreted differently by different people. As such, they are confusing terms. However, I will use them in the way they are quite often used in the literature, as technical predicates that indicate a theoretically relevant distinction in directivity. This will become clearer from the discussion below.

[3]See Horn 2002 for similar contrasts. For instance, (II) illustrates that different kinds of exemplification may point to a positive/negative contrast (cf. Dayal 1998).

(II) a. A few students came to my party. For example, Bill did / ??didn't.
b. Few students came to my party. For example, Bill ??did / didn't.

Whereas 'a few' triggers plain exemplification, negative 'few' triggers counter-exemplification.

[4]That is, in this sense negative quantifiers are reminiscent of Wason's (1959) characterisation of negative statements in terms of deviation from what is expected.

[5]To be precise, a type (1,1) quantifier can be monotone with respect both arguments. Monotonicity in the left argument is often called *persistence*. In what follows, we focus on the second argument only.

[6]A complication is formed by the possibility that 'most' might give rise to implicatures. See endnote 12 for discussion.

[7]See Morzycki 2004; Katz 2005; Nouwen 2005 for a different use of such adverbs.

[8]A reviewer notes that the point made below about (33) is really independent of the adverb 'surprisingly'. S/he observes that even without such an evaluation, (33-a) (resp. (33-b)) would still indicate that more (resp. fewer) people than expected came. I agree that the adverbs are not crucial, but I disagree that the readings have to involve expectation. For instance, the same point as below can be made about *what is desired* instead of *what is expected* when 'surprisingly' is replaced by 'unfortunately'.

[9]The claim that predicates like 'surprise' are monotone is not easily defendable. This is because standard tests are useless due to several independent features of such predicates. (See Nouwen 2008b for details). Most importantly, 'surprise' is factive. Consequently, (III-a) does not entail (III-b), for (III-a) does not entail that Billy wore a dress to the party. (An anonymous reviewer rightly pointed out that the role of factivity needs to be clarified. Thanks also to Crit Cremers for discussing this point with me on an earlier occasion).

(III) a. I'm surprised that Billy came to the party.
b. I'm surprised that Billy came to the party wearing a dress.

The monotonicity of 'surprise' operates on a deeper level than what may become visible using tests like (III). It is a constraint on what people's expectations/surprise may look like. If some actual or non-actual $p$ (would) surprise(s) someone, then it cannot be the case that this surprise only holds for some particular worlds in which $p$. The surprise should hold for all normal situations in which $p$ is true. Compare this with someone thinking it 'possible' that $p$, for which such a constraint clearly does not hold.

[10]This said, monotonicity has been successfully argued to account for various other aspects of quantifiers. For instance, Geurts 2003 shows that monotonicity properties of quantifiers play a role in syllogistic reasoning and Geurts and van der Slik 2005 show that monotonicity may explain some specific patterns of how quantified sentences are processed.

[11]Nouwen 2008c argues that 'no less than'-quantifiers trigger implicatures which render them non-monotone. This, by itself, however, does not suffice to explain the observation, for the reasons explained in endnote 12.

[12] A further complication is formed by non-monotone quantifiers. A sentence like 'exactly twenty percent of the students came to the party' licenses the inference that exactly eighty percent did not. Still, non-monotone quantifiers like 'exactly twenty percent' are awful licensers of complement anaphora. This is consistent with data on upward entailing quantifiers that may give rise to a downward monotone implicature and thus end up being non-monotone. As an anonymous reviewer points out that 'most' might give rise to a 'not all' implicature, but this implicature does not suffice to license complement anaphora. Having said this, non-monotone quantifiers do behave as expected under evaluative predicates. An example like (IV) does not really fix the direction in which the amazement should be sought. For instance, (IV) could be because one expected more people, or fewer, or simply because it was Jasper's thirty-fifth birthday.

(IV) Amazingly, exactly thirty-five people came to Jasper's party.

[13]The modal nature of superlative modifiers is illustrated in many other ways too. See Geurts and Nouwen 2007 for the full details.

[14]One might think that GQT is thus reduced to a general theory of lexicalised quantifiers. This would lead to a very ad hoc characterisation of what a quantifier is, for it would have to exclude operators like 'only' and 'many'/'few' (cf. Solt 2006).

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