The Acquisition of Quantification across Languages: Some Predictions

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1. Introduction

In this paper we review factors that are expected to affect the order of acquisition of quantifiers across languages. We draw a distinction between language-wide and language-specific factors as well as factors that relate to the biological and social profile of the learner (such as gender, socio-economic status and schooling). We then propose predictions for what cross-linguistically similar patterns may arise. This exposition provides the theoretical background against which a major empirical project has been undertaken, with the goal of documenting the extent to which the acquisition of quantifiers proceeds uniformly across languages. Here we summarize the scope of the project, the specific hypotheses under test, and other factors that must be considered in analysing the outcome of the ongoing empirical work. We conclude by discussing the implications of these investigations for the interface between linguistic and non-linguistic cognition. But first we turn to cross-linguistic similarities in the meaning of quantifiers in the following section.

2. Quantification: cross-linguistic similarities and differences

Quantificational expressions allow us to precisely express generalizations. For example, the generic 'Dogs like to chase cats' turns into a much more precise claim when we change the subject to 'some dogs', 'all dogs', or 'most dogs'. The meaning of these quantifiers is traditionally taken to correspond to set-theoretical logical concepts (among others see Barwise & Cooper, 1981;

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Gamut, 1991). For example, the meaning of the English quantifiers 'all' and 'some' is considered to be equivalent to that of the universal and existential quantifier ('∀' and '∃') and the truth-conditions of quantified sentences are given using set-theoretical tools as in (1), where 'iff' is 'if and only if', '∩' is the intersection of two sets, '∅' is the empty set, and a is an element of a set:

1. (a) 'All As are Bs' is true iff $A \cap B = A$
   (b) 'Some As are Bs' is true iff $A \cap B \neq \varnothing$
   (c) 'No As are Bs' is true iff $A \cap B = \varnothing$
   (d) 'Some As are not Bs' is true iff there exists a, such that $a \in A$ and $a \notin B$
   (e) 'Most As are Bs' is true iff $A \cap B > |A - B|$

Recent typological research in semantics suggests that most human languages contain these and other quantifiers, though it is debated whether in fact all of them do (Matthewson, 2004). However, for the languages that do have universal, existential, and other quantifiers, it is reported that the meaning of these quantifiers exhibits striking similarities cross-linguistically (von Fintel & Matthewson, 2008).

The similarities in the meaning of quantifiers extend to their actual use. For example, speakers are required not only to be truthful, but also to be informative up to a contextually dictated level: speakers should not describe a situation for which they know that all the apples are in the boxes by saying that 'some of the apples are in the boxes'. Even though the sentence would be strictly speaking true of that situation, the speaker would be violating conversational norms that enjoin him not to be under-informative. Such pragmatic considerations are founded on principles of human rationality (Grice, 1989) or cognitive economy and cost–benefit optimisation in the exchange of information (for different approaches see Levinson, 2000; Sperber & Wilson, 1986/1995). Cross-linguistic investigations suggest that pragmatic maxims are at play in every human language, with informativeness being the flagship example (for refutation of early claims to the contrary see Prince, 1982).

These cross-linguistic similarities in the meaning and use of quantifiers are exactly what one would expect if, across languages, these quantifiers are indeed the linguistic counterparts of the same set of abstract concepts. Therefore, the meaning and conventions of use of these expressions are to some significant extent independent of the specific grammatical and lexical configuration of particular languages.

On the other hand, the lexical and syntactic realization of logical vocabulary in general, and quantifiers in particular, differs substantially from language to language. Regarding lexical differences, some languages have specialized words with the dedicated function of expressing quantity, while others recruit expressions from the class of common nouns. A good case in point is the proportional quantifier which is often expressed cross-linguistically through a

quantificational determiner or an adjective (e.g. English 'most', a determiner, and in German 'die meisten', an adjective). However, in many languages proportional quantifiers are formed through nominalizations which yield expressions meaning 'a majority of' or 'the biggest part' (for example, French, Spanish, and Russian; von Fintel & Matthewson, 2008). As an example of syntactic variation, languages differ in concord with negation: while in standard British English a single negative quantifier suffices to express negation, 'None of the apples are in the boxes', other languages use two negative markers, a negative quantifier and a negative particle, e.g. French, 'Aucune pomme n'est dans le boites'. Double negation in these cases does not correspond to a positive statement (as it would be the case for English 'No apples are not in the boxes'). Instead, the meaning is similar to that of the English single negative. Other lexical and syntactic features that vary across languages include the order of the elements within the quantifying phrase (quantifier–noun order or the reverse) and whether a partitive expression can be used (e.g. 'some *of the*') among others.

Quantifiers therefore pose an interesting case at the interface between language-specific and language-general cognition. For speakers to know the meaning of quantifiers, and to know how to use them felicitously, they must master set-theoretical concepts and principles of rational information exchange that seem to be independent of the specific language that they are speaking. However, they must also be competent with the way the relevant language instantiates quantifier meaning and syntax.

In this paper we explore how language-wide similarities in meaning and use, and language-specific lexical and syntactic choices, may give rise to consistent patterns of acquisition across a large sample of languages. Quantifiers are an ideal test-bed to study this, precisely because their comprehension involves both the lexico-syntactic choices in the particular languages and the cross-linguistically robust similarities in meaning and use. This exploration is the theoretical background to an ongoing empirical project on the acquisition of 'all', 'some', 'none', 'some…not', and 'most' by 5-year-old children speaking one of 25 languages. The language sample for the empirical project, which represents 10 major language groups (as well as a language isolate), provides a wide range of syntactic and lexical diversity that allows us to investigate any effects of language-specific choices.

3. The empirical setting

As part of the larger project of COST Action A33 (see acknowledgements footnote), the empirical investigation focuses on the comprehension of quantified sentences by 5-year-old children and adults speaking one of 25 languages: Basque, Catalan, Croatian, Cypriot Greek, Danish, Dutch, English, Estonian, Finnish, French, Georgian, German, Standard Greek, Hebrew, Italian, Lithuanian, Maltese, Norwegian, Polish, Russian, Serbian, Slovak, Spanish, Turkish, and Urdu. These represent ten major language groups (Baltic, Finnic,

Georgian, Germanic, Greek, Indic, Romance, Semitic, Slavic, and Turkic), belonging to five of the main language families in the world (Afro-Asiatic, Altaic, Indo-European, Kartvelian and Uralic/Finno-Ugric) as well as a language-isolate (Basque).

Children are being tested at nurseries or primary schools following the ethical protocols designated by the host institutions of the participating researchers. They will be administered the 'Cavegirl task' (see Katsos et al., 2011, for a full list of items and task information) which was designed to test the comprehension of quantified sentences. In this task participants are helping a fictional cartoon character, the Cavegirl, to learn to speak their own language. They hear the Cavegirl produce utterances of the type '[Quantifier] of the [objects] are in the boxes' for each of the quantifiers in (1). After each utterance, children are asked to evaluate whether what the Cavegirl said was "right" or "wrong", given a visually represented situation. If participants answer "wrong", they are further asked to tell the Cavegirl why the utterance was wrong. This is done to check whether participants were evaluating the utterances on the grounds of the quantity mentioned or not (e.g. other research has documented that populations with developmental disorders may occasionally reject utterances on unrelated grounds, e.g. 'Bicycles don't fit in boxes').

There are two types of visual situations for each quantifier, one which renders an utterance with this quantifier logically true and informative and one which renders an utterance logically false. For quantifiers 'some', 'some…not', and 'most' there is also a third type of display that renders an utterance logically true but pragmatically under-informative (for 'some' and 'most' this is a display where all of objects mentioned are inside the boxes; for 'some…not' this is a display where none of the objects mentioned are inside the boxes). The task is preceded by a warm-up session where children are familiarised with the Cavegirl, the task demands, and the pictures of the objects mentioned in the sentences.

The actual quantifiers used in each language were selected by researchers who were native speakers of that language. Where more than one lexical item was available, the choice was predominantly guided by considering which item would be most familiar to children of the age-group. Where possible, this decision was informed by investigating corpora of child-directed speech. Where not, researchers took a decision after consultation with colleagues and/or school-teachers. Adult participants were also tested to ensure that the quantifiers chosen were indeed true, false or under-informative for the respective visual displays as hypothesized.

4. Developmental predictions
4.1. Predictions based on similarities in meaning and use

Let us first turn to predictions relating to cross-linguistic similarities in the meaning and use of quantifiers. Previous single-language studies document that differences in the meaning and use of quantifiers lead to measurable effects at

the neurological (Troiani, Peelle, Clark & Grossman, 2009) and behavioral level for adult processing (among many others, Cummins & Katsos, 2010; Hackl, 2009; Szymanik & Zajenkowski, 2010) and for child acquisition (e.g., Hanlon, 1988; Katsos, Andrés Roqueta, Estevan & Cummins, 2011). Based on these studies, the following hypotheses can be deduced from the meaning of the specific expressions that we study.

Hypothesis 1 relates to *polarity* and the fact that negation is a linguistically and psycholinguistically marked function (Just & Carpenter, 1971). We could therefore expect that children's rates of successful comprehension will be higher with positive quantifiers ('all', 'some') than negative ones ('none', 'some…not').

Hypothesis 2 relates to *totality* and the fact that quantifiers whose reference set is the maximum possible set appear earlier in acquisition over quantifiers whose reference set is a portion of the potential reference set (Hanlon, 1988). We could therefore expect that children's rates of successful comprehension will be higher with universal ('all', 'none') than existential quantifiers ('some', 'some…not').

Hypothesis 3 relates to semantic *complexity* and the fact that while both 'some' and 'most' refer to an under-specified portion of the total, 'most' stipulates an additional constraint, namely that this portion be more than half (in fact the meaning of 'most' is likely to be richer than 'more than half', but this rough paraphrase suffices for stating this hypothesis; see Hackl, 2009; Pietroski, Lidz, Hunter, & Halberda, 2009). It is expected that children's rates of successful comprehension will be higher with existential 'some' than proportional 'most'.

Turning to the use of quantifiers, our final hypothesis, 4, relates to *informativeness* and truth. Young children seem to make extensive use of pragmatic principles for word learning and disambiguation (Clark, 1990), and they are also aware that under- and over-informative utterances are not optimal (Davies & Katsos, 2010; Katsos & Bishop, 2011; Katsos & Smith, 2010). Nevertheless young children do not consider violations of informativeness to be as grave as violations of logical truth, and do not categorically reject under-informative utterances (e.g., Guasti, Chierchia, Crain, Foppolo, Gualmini & Meroni, 2005; Noveck, 2001; Papafragou & Musolino, 2003). We could therefore expect children's rates of successful comprehension to be higher with true-and-informative or patently false utterances than with true-but-under-informative utterances (for 'some', 'some…not', and 'most').

Crucially, the prediction is that the four patterns described above will obtain in every language in our sample, precisely because these patterns rely on cross-linguistically similar properties of the meaning and use of quantifiers.

4.2. Predictions based on language-specific features

Moreover, it is likely that language-specific lexical and syntactic properties of quantified utterances will affect the pattern of acquisition. For example, in

terms of syntax, it is possible that negative concord, the word order within the quantifier phrase, and the word order of the sentence will have an impact on comprehension. However, it is not necessarily clear what the direction of the influence will be in each case (as we are not aware of research that could help predict whether, for instance, the quantifier–restrictor order is easier to acquire than the inverse).

In terms of the lexicon, it is possible that using an expression from a specialised class of quantifiers may favourably impact acquisition because of the close paradigmatic relations within the class. For example, it may be easier to master the meaning of English 'most' than French 'la plupart' or Spanish 'la mayoría' because 'most' belongs to the paradigm of quantifiers which includes 'all', 'none', and 'some'. Contrasts between members of the paradigm may therefore facilitate the acquisition of their meaning. These contrasts may be less salient in languages employing an expression from a different class. It is also possible that the number of syllables of each expression is an important factor. However, as with many of the syntactic factors reviewed above, we are not aware of relevant research that could bear on these hypotheses, and so it is an open question whether these factors will turn out to be significant predictors of children's performance. Finally, another potentially important factor may be the explicit presence of a partitive marker (like English 'of the'), which may positively affect children's performance with under-informative utterances (Pouscoulous, Noveck, Politzer & Bastide, 2007; but see Banga, Heutinck, Berends & Hendriks, 2009).

4.3. Predictions based on biological and social properties of the population

Finally, a range of non-linguistic factors may also be important predictors of the acquisition of quantifiers. These include social factors, such as children's socio-economic background, and whether they are attending school at the time of testing. From a biological perspective, exact age and gender may also have a role. As regards gender, it is reported that linguistic skills are generally better among females than among males, even in children as young as 2–3 years (Bornstein, Haynes, Painter, & Genevro, 2000; Dionne, Dale, Boivin, & Plomin, 2003) with girls beginning to talk earlier (Murray, Johnson, & Peters, 1990), and to acquire vocabulary faster (Roulstone, Loader, & Northstone, 2002). Some of these differences may be attributed to neurological differences in how language is processed (Burman, Bitan, & Booth, 2008). On the other hand, it has been suggested that males may outperform females when it comes to reasoning with mathematical concepts, due to higher aptitude with logical and set-theoretical concepts (though for a critical review see Spelke, 2005).

To the extent that these gender differences are indeed valid, quantification seems to be a case where the gender biases compete against each other. On the one hand, females may benefit from an overall advantage with learning vocabulary, while on the other hand males may benefit from an advantage with set-theoretical concepts. A further interesting prediction relates to Hypothesis 4

of the language-wide predictions, on the ability to detect violations of informativeness. It has recently been reported that differences in cognitive style, and specifically the prevalence of autistic features within the neuro-typical population, predicts sensitivity to Gricean pragmatic principles. Nieuwland, Ditman & Kuperberg (2010) reported that participants' scores in the Communication subscale of the Autism Quotient (Baron-Cohen, Wheelright, Skinner, Martin & Clubley, 2001), a measure which quantifies the prevalence of autistic traits, correlated with ERPs to utterances that violated the maxim of informativeness. Participants with high scores in the Autism Quotient (indicating stronger presence of autistic traits) showed weaker N400 effects, indicating that they were not as sensitive to underinformativeness as participants with lower scores. Given that the prevalence of autistic traits in higher within the male population at large, it is therefore possible that sensitivity to violations of informativeness will be attenuated in boys compared to girls.

5. Discussion

When completed, the present study will provide a rich array of cross-linguistic data enabling us to evaluate the hypotheses presented in section 4.1, and to explore the significance of the additional factors touched upon in the above discussion. In this section, we briefly discuss the implications of future findings for our understanding of the interdependence of linguistic and non-linguistic cognition. We are particularly interested in the four language-wide hypotheses. If the empirical investigation were to reveal that these patterns hold across every language in our sample one could be entitled to ask what is the underlying foundation of these effects. A plausible response is that the language-wide similarities in aspects of quantifier meaning and use are underpinned by universal trends in the development of non-verbal cognition that may emerge at the pre-linguistic stage. For example, the relative difficulty of negative quantifiers predicted in hypothesis 1 might be attributable to universal developmental trends in how and when child become aware of the presence as opposed to the absence of entities. Similarly, the relative processing complexity of the non-linguistic comparison of subsets that is required for the meaning of 'most', and the importance of children's counting skills (Halberda, Taing, & Lidz, 2008) may underline the effects of hypothesis 3; while a perceptual / conceptual advantage for identifying the full membership of a set may underline the effects of totality in hypothesis 2. Perhaps the only case where a purely linguistic explanation would be available is hypothesis 4, on children's sensitivity to informativeness. In this case, the cross-linguistically universal difference between the gravity of violations of logical truth and of violations of conversational felicity (Katsos & Bishop, 2011) may suffice to account for any patterns that arise.

Having pointed to a potential relation between the development of non-verbal cognition and competence with the corresponding linguistic expressions, it would be misleading to suggest that the direction of influence is uni-

directional. Instead, research in related fields such as the acquisition of numerals suggests that in the absence of the linguistic expressions of number (i.e. numeral words), the ability to reason with numerosities above the small range of the subitising numbers is restricted (see Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011, and the discussion therein). As such, it is very likely that the acquisition of quantifiers feeds into the development of the mastery of the corresponding non-verbal set-theoretical concepts. It is therefore possible that the emerging picture will consider the relative contribution of linguistic and non-linguistic cognition to children's overall competence with quantification, rather than identifying one factor as being predominant.

In fact some evidence that the acquisition of quantification is indeed integrally related to language development, and perhaps less so on the development of non-verbal cognition, is already available. Research suggests that competence with the meaning and use of quantifiers is in fact related to children's overall competence with vocabulary and grammar (Katsos et al., 2011; also Surian, Baron-Cohen & van der Lely, 1996) rather than in line with their overall non-verbal IQ or social cognition. Studies in language disorders are particularly useful in cases where the relative contribution of different factors is under investigation. In the studies cited above, it has been found that children with language impairment who have age-appropriate non-verbal IQ, perform in line with what would be expected based on their grammatical and lexical competence rather than their non-verbal IQ.

This last finding raises the possibility that competence with quantification may be a good indicator of competence with grammar and vocabulary as a whole. If this is so, then quantifiers and other similar expressions may be used to develop benchmarks for assessing a child's language skills based on meaning and use, rather than the traditional morphosyntactic criteria that are usually employed (e.g. in TROG, Bishop, 2003). The additional fact that benchmarks based on meaning and use might be cross-linguistically similar, allows for the possibility of a cross-linguistically valid tool of language assessment.

Obviously, the validity of several of the predictions and claims made in this paper will be tested through ongoing and future empirical investigations.

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